

BBC



THE STRANGE SCIENCE OF CATS

Everything you know about your feline friend is wrong...



**Secrets of
sunken Egypt**
Ancient city explored

**How to build
a planet**

Distant worlds and
new discoveries

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SCIENCE AND TECHNOLOGY

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ISSUE 259 / SEPTEMBER 2013

HOW SLEEP CAN MAKE YOU SMARTER

THE AMAZING SCIENCE OF
HOW YOU LEARN WHEN
YOU'RE NOT EVEN AWAKE



THE ULTIMATE EXPERIMENT

Plans for the next
generation particle
collider unveiled



Q&A

- Which came first - time or space?
- Is it defensive to cross your arms?
- Why have Roman buildings outlasted newer ones?



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WELCOME TO FOCUS



WHEN I WAS taking exams, I often wondered if I could improve my grades by playing French tapes as I slept, or by sticking diagrams on the ceiling above my pillow. I never actually tried these experiments, but these are the kinds of questions now being investigated by sleep researchers like Dr Penelope Lewis. On p34, Penelope reveals how sleep really can make you smarter.

Sleep is something cats are particularly good at, but if you think you know our feline friends, think again. On p58, Dr John Bradshaw, seen on the recent BBC *Horizon* episode *The Secret Life Of The Cat*, reveals seven myths about moggies.

From pets to particle physics, and a next-generation collider is already being planned to replace the LHC. When I visited CERN earlier this year, talk was that the new machine would be bigger, faster and longer. It's called the International Linear Collider (ILC) and you'll find more about it on p56.

The ILC will study the tiniest components of matter but there are still mysteries surrounding much bigger objects - planets. We complement Richard Hammond's BBC series *How To Build A Planet* on p42 by exploring how different bodies are formed.

Until next issue,

Graham

Graham Southorn, Editor



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APPEARING IN THIS ISSUE...



Michael Banks

The news editor of *Physics World* is the perfect person to reveal how the successor to the

Large Hadron Collider could unlock some of the biggest mysteries of nature. Turn to p56 to find out more about the International Linear Collider.



John Bradshaw

John first came to our attention when his acclaimed book *In Defence Of Dogs* exploded several

myths about our canine companions. His latest book is *Cat Sense* and he reveals some of the hidden secrets of felines on p58.



Penelope Lewis

Penelope lectures in the Sleep And Memory Lab at the University of Manchester and has

just written a book, *The Secret World Of Sleep*. On p34 she explores how you can supercharge your brain with the help of the right kind of kip.



Matthew Symonds

The editor of *Current Archaeology* casts an expert eye over new finds from

Heracleion, the sunken city of Ancient Egypt that lay forgotten underwater for 1,200 years. Matthew investigates the latest discoveries on p50.



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On p32, computer scientist and author **Dr Peter Bentley** looks at the latest developments in artificial intelligence

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insiders

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the more we know about you, the better placed we are to bring you the best magazine possible. So we'd like to invite you to join our online reader panel, 'Insiders'.

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We look forward to hearing from you soon.

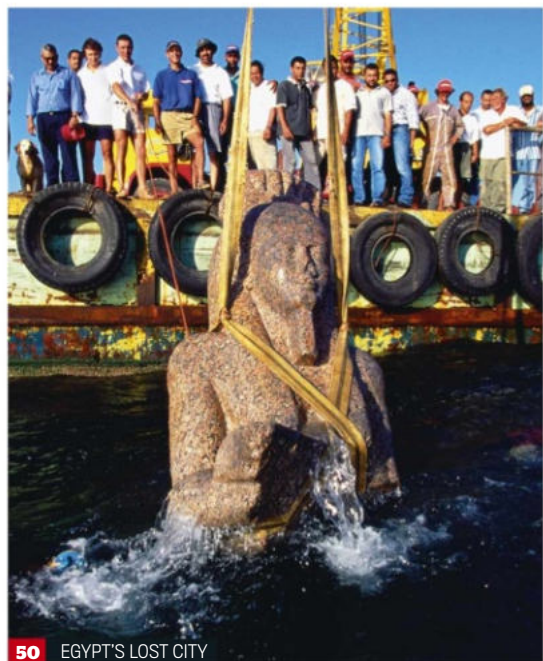
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MegaPixel



Bug-eyed caterpillar

THIS IS THE larva of a Pink Underwing moth (*Phyllodes imperialis smithersi*), spotted in the Australian subtropical rainforest. It's confined to a small strip of land spanning the Queensland and New South Wales border.

The eyespots separated by bone-like markings aren't the only ones on the larva of this endangered subspecies. "There are actually two pairs of eyespots," says Dr Dave Britton, an entomologist at the Australian Museum in Sydney. "The brightly coloured ones [pictured] are at the front, then behind them on the first abdominal segment there are a pair

that are much more convincingly like the eyes of a reptile, complete with an iris and eye-slit."

The false eyes are likely to be a defence mechanism. "I do not know of any study that has confirmed that the eyespots have adaptive significance in terms of scaring away predators," says Britton, "but intuitively, that is what they would appear to do."

The adult moth only lives up to its name while flying at night or when disturbed, revealing its brilliant pink and white hind wings.

PHOTO: REX



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MegaPixel

Planet transit

THESE GOSSAMER-LIKE threads trace out aircraft flight paths across the planet, showing just how connected much of our world has become. In total, 58,000 routes are shown.

"One of the most interesting features of this illustration is that I didn't need to add a base map to show the continents and oceans," says Michael Markieta, a transport planner in the Toronto office of engineering and design firm Arup. "The flight routes themselves trace the shape

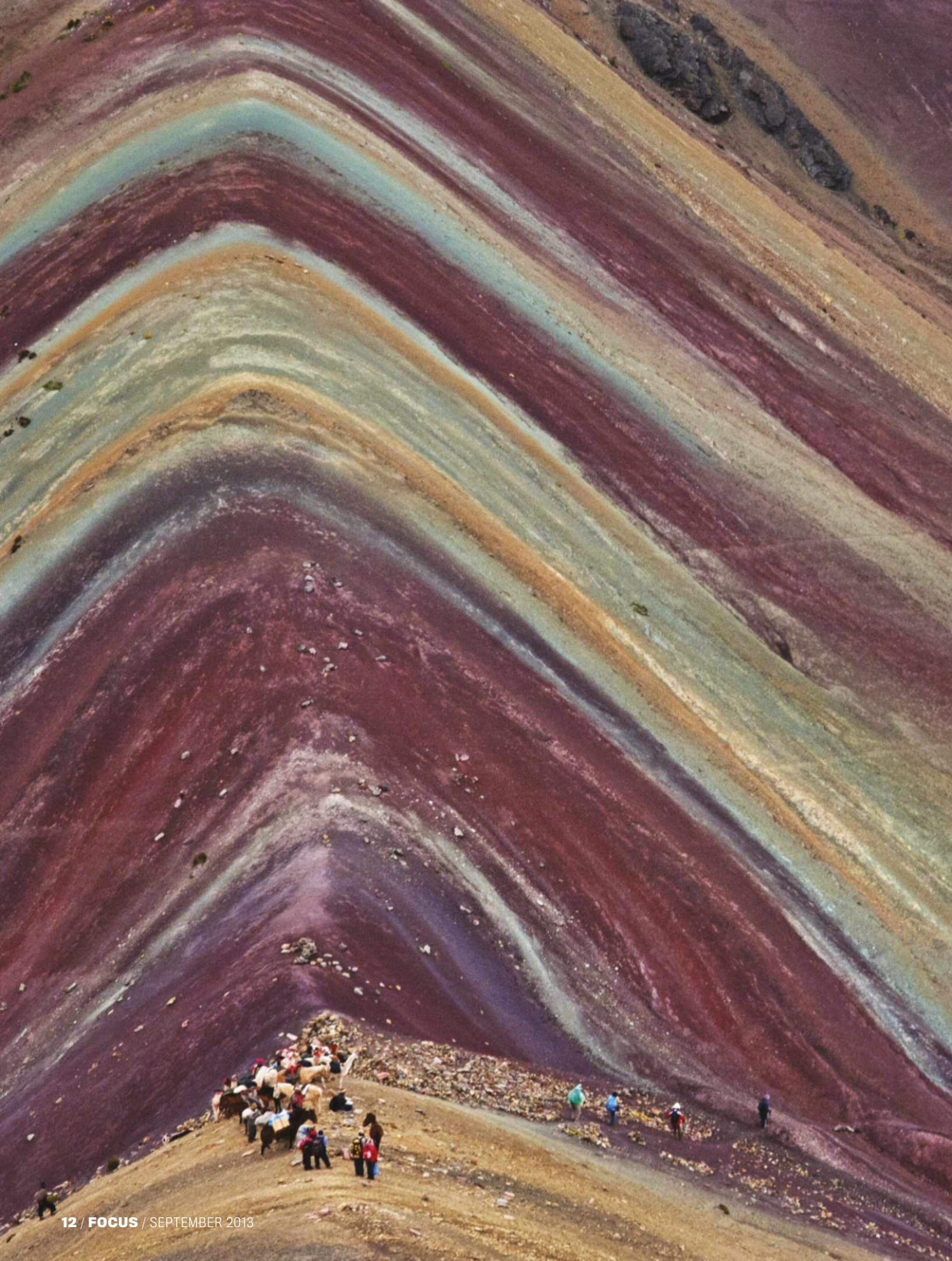
of the Earth's coastlines quite effectively because humans have historically settled in coastal regions."

The flight paths were taken from an online database, openflights.org, before being plotted. Overlapping flights are coloured lighter shades of blue, making the busiest areas brighter.

Markieta says the map provides the aviation industry with a simple way to spot potential new routes.

PHOTO: MICHAEL MARKIETA







MegaPixel

Rainbow mountain

THE COLOURS SEEN in the foothills of the Ausangate mountain in Peru tell a story about our planet's history. Each of the bands represents a moment in time – thousands or maybe tens of thousands of years in the Paleocene epoch, over 50 million years ago. While all the rocks are sedimentary, formed from mud and sand that settled out from rivers and lakes, their colour reveals the conditions at the time they were hardening.

The red stripes get their colour from hematite, a water-free mineral that consists only of iron and oxygen. "It's the same mineral that gives the planet Mars its distinctive colour and forms in arid environments with little water," says Dr Matt Genge, a senior lecturer in Earth and Planetary Science at Imperial College London. So here the lake that deposited the sediment must have dried out before the rock had hardened.

The yellow and brown layers are dominated by the minerals limonite and goethite respectively. Both contain water and show there were wetter periods in the region's history. The green layers would have formed when there was a lot of plant matter – again in a wet period.

PHOTO: PERU TRAVEL NOW

REPLY

Your opinions on science, technology and *Focus* magazine



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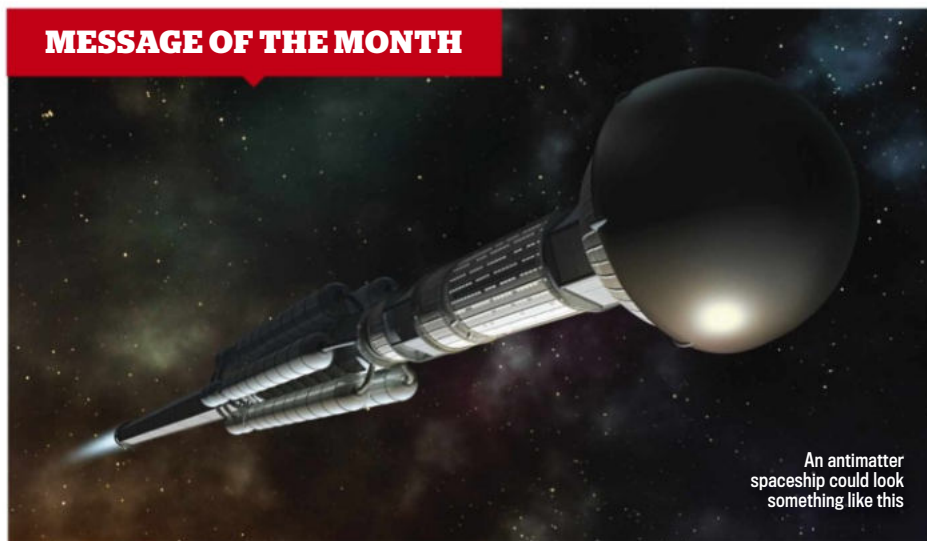
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Letters may be edited for publication

MESSAGE OF THE MONTH



An antimatter spaceship could look something like this

Fly me to the stars

'Journey To The Stars' (p70, Summer 2013) was a fine and very interesting article on future technologies with which we might, one day, set sail for the stars – and beautifully illustrated too! But two problems... First, why no mention of anti-matter? Not just the fuel for Scotty's warp engines in *Star Trek*, anti-matter is real stuff that just might make 'matter-anti-matter' propulsion possible in the future. There are many problems to be overcome before such a drive is feasible, not least that anti-matter is very difficult and very expensive to manufacture in useful quantities. But who knows what the future might bring?

Also, you included warp-drive in your review, and implied that it might be do-able soonish, by including it in an article that discussed technologies that really do have a basis in modern-day science. You said 'top-secret' research at NASA was being

carried out, on the existence of 'negative energy', which could be utilised for a warp propulsion system. This is, to the best of my awareness, just speculation as to what might be, as opposed to what actually exists, in order that we might send a future generation to the stars. You couldn't have surprised me more if you had said that NASA hope to have a prototype warp drive spaceship within 50 years! Otherwise, it was a decent article in a fine magazine.

Graham Rich, London

Who's to say that antimatter propulsion might be possible one day, but at the moment it doesn't last long. In 2011, an experiment at CERN manufactured 309 antihydrogen atoms, which lasted just 17 minutes. As for warp drive, NASA has reportedly been studying faster-than-light travel based on an 'Alcubierre Drive'. But I'm not holding my breath... – Ed

Write in and win!

The writer of next issue's Message of the Month wins a Marley Chant Bluetooth speaker, worth £79.99. Chant is a portable audio system that comes with a carry bag and a built-in battery, plus a 3.5mm stereo input for wired connection to other devices.
www.thehouseofmarley.co.uk



Five a day is OK

I read, with some dismay, in the Summer edition (p102) that the banana is radioactive! I have been eating two bananas a day, breakfast and teatime, for at least five years, convinced that they were good for me. Does this mean that I have had the equivalent of $2 \times 365 \times 5$ divided by 200 = approx. 18 chest x-rays, and it's shortened my life by $18 \times 11 = 198$ minutes? Am I now a walking radioactive health hazard? And I thought that fruit was a healthy option!

Eddie Newnes, North Wales

For a fatal radioactive dose from a banana you'd have to eat 20 million in your lifetime, or 700 a day. See <http://bbc.in/pFXVTx> – Ed

Blood groups

On p63 of the July issue, a reader asks in Q&A, 'Do other species have different blood groups?'. Perhaps it should also be noted that although mammalian blood contains iron in the haemoglobin to transport oxygen around the body, different metals are used in other species. For instance, some of the invertebrate species such as those in the phylum Mollusca, which includes snails, slugs, octopus and squid, have blood containing copper. Hence their blood appears bluish in colour. And, the marine organisms 'sea squirts', which are in the phylum Chordata – the same as mammals – have the metal vanadium in their blood cells.

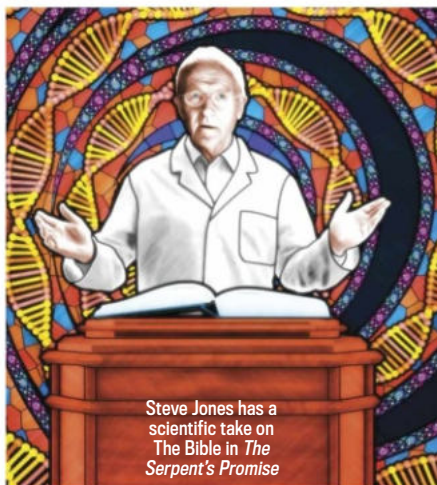
Paul Biggin, Watford

Bible science

The idea of Noah's Ark being written off as nonsense because no one has found the wreckage is, I think, a very poor scientific stance (p64, Summer). Partly because, being wooden, the remains would likely have rotted away long before anybody started looking for them. Carl Sagan is quoted as saying 'Absence of evidence is not evidence of absence', ie not being able to prove something does exist doesn't constitute proof that it doesn't.

Jon Riley, Salford

I am confused. Steve Jones states, when talking about Adam and Eve living



100,000 years apart, that “when you trace the genes back, the last common male ancestor appears 100,000 years earlier than the last common female ancestor.” From this, I concluded that the last common male ancestor is known to be 100,000 years older. However, in the answer to why that might be, Prof Jones gives reasons for going further back in time to find the last common female ancestor – a diametrically opposite position to that which he stated earlier. Was it a misprint?

Steve Jones (the other one!), Bedford

Something was lost in translation. In Prof Steve Jones book The Serpent's Promise, he writes: “The birthday of Eve can be tracked down in the same way. She lived, those sums tell us, rather less than two hundred thousand years ago, well before Adam. The two can never have met.” - Ed

More wonder materials

I remember reading about ‘glassy metals’ a few years ago and how they were going to change everything once they figured out how to make them cheaper. Why no mention in your article? Have they been bypassed by something else?

Boyd D Dunson, Middleway, West Virginia

I think that you should have added carbon aerogel to the list because its lightly stacked molecular structure is so light it has a density of 0.6g per cm³. It can sit on a grass blade without it bending.

Luke Davies

I recommend nanocrystalline cellulose for the top 10. It would be a green replacement for plastics and aluminium.

David Robertson

Keeping cool

Having worked in Saudi Arabia on a new major city construction project in

1990, where temperatures often reached 40° but with minimum humidity, I was intrigued to read your article on keeping cool (p50, Summer). This massive project involved dumper-trucks crossing from area to area. To avoid accidents, ‘flag-boys’ were employed to sit at road junctions all day. They were swathed in layers of thick black coats and jumpers from head to toe as well as wearing hard hats. As a sunbathing Brit, it puzzled me why these poor chaps were so overdressed in such extremes of heat. I don’t doubt they were adequately supplied with drinking water, so I came to the conclusion that either they were insulated by the layers to absorb the heat or were so dressed to minimise evaporation.

John Thexton

I found your article ‘Are our summers about to get better’ (p35, Summer) amazing. It seems to be completely out of sync with what is happening in the real world and with what scientists of all disciplines are increasingly saying. What we are experiencing is a number of years (the number ranges from 12 to 20) when temperatures have not increased beyond the limits of acceptable error. All the models that your article refers to have been based on the assumption that temperatures will continue to increase indefinitely in line with the global increase in CO₂ emission. Every one of those models, by not incorporating the current flatlining of temperature, has been proved to have no ability to predict what the climate will do in the future. It was this problem and the phenomenon of ‘weird weather’ that prompted the Met Office on 18 June to convene a meeting of scientists and others to try to answer the question ‘What on Earth is going on?’. The general view expressed at the meeting was that we don’t know. Not only are the models and predictions wrong, the scientists can’t explain why.

Jasper Solomon, Totnes

YOUR COMMENTS ON TWITTER

On facebook.com/sciencefocus we asked: **What did you think of Dara O Briain's Science Club on BBC Two?**

@DaveHenniker It was the best yet. Fascinating science and excellent guests

@stewgreendotcom Good stuff. Scientists can present themselves – don’t need a celebrity presenter

@RichardLKing Mainly engineering and technology being masqueraded as science as usual; Max Tegmark should have had more time

FOCUS

SCIENCE AND TECHNOLOGY

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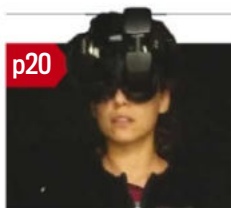
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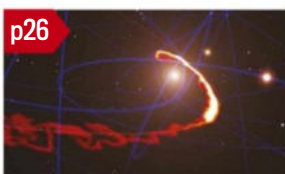
News and views from the world of science



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THE MIND OF A CHILD

How virtual reality is letting us enter the small world of children



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BLACK HOLE VS COSMIC CLOUD

Astronomers are on watch as a giant gas cloud is torn apart by a monster black hole



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LOUNGE LIKE A LIZARD...

...for 23 million years. Amber-preserved specimen found

THE BIG STORY

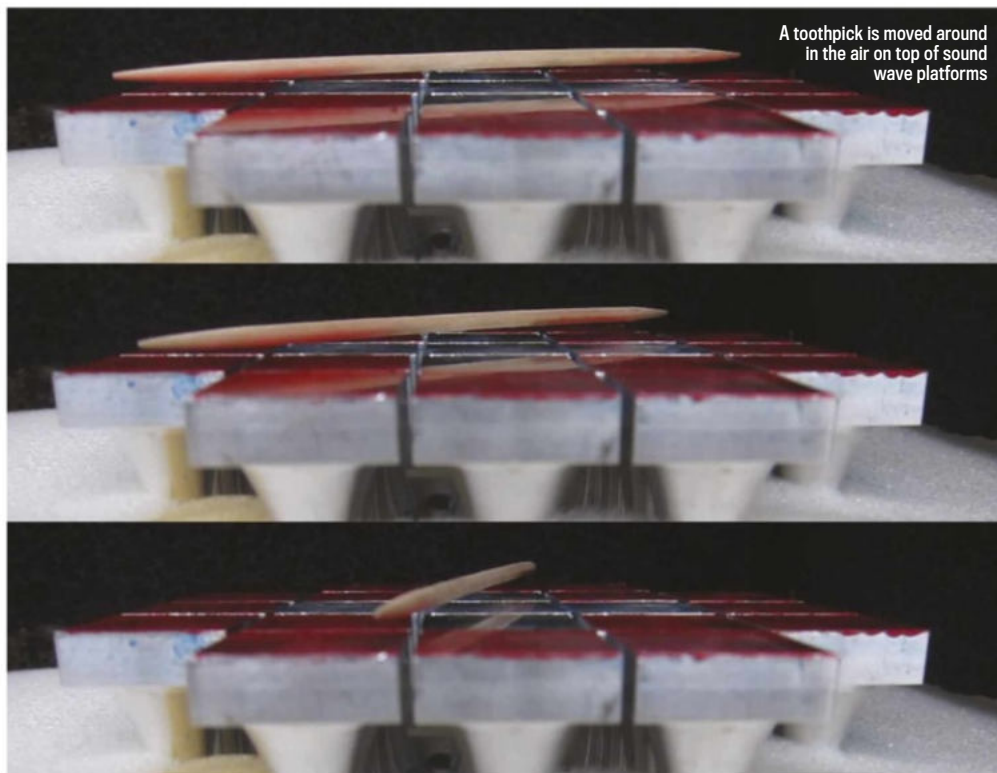
A sound new way to levitate

Technique uses sound waves to float objects and carry out experiments

FLOATING COFFEE BEANS, dancing water droplets, flying toothpicks – if you walked into one Swiss laboratory, you'd be forgiven for thinking you were seeing things. For the first time, scientists have found a way to move and manipulate objects in mid-air using sound waves. The breakthrough means 'acoustic levitation' can be used to create new materials, carry out delicate experiments, and even, in theory, levitate humans. ➔

Coloured drops of fluid are levitated by the revolutionary sound wave experiment

PHOTO: DANIELE FORESTI



A toothpick is moved around in the air on top of sound wave platforms



Acoustic levitation was invented by NASA in the 1980s but until now, scientists could only hold an object in place or rotate it on the spot. Now researchers at the Swiss Federal Institute of Technology in Zurich have developed a way to move objects and handle more than one at the same time.

The system uses vibrating square platforms, each about the size of a thumbnail, that send out sound waves and reflect them off a surface above. At certain frequencies, the reflected waves combine with the upwards-moving waves to create a pattern known as a 'standing wave'. This has certain points, or 'nodes', that stay fixed even as the wave oscillates. An object placed at one of these sweet spots can float in mid-air, with the force from the sound waves balancing the downwards pull from gravity.

By lining up a series of platforms and varying the strength of the sound waves from one to the next, the researchers can carry objects from platform to platform. To demonstrate, they dissolved a floating coffee

granule by moving it into a droplet of water and even levitated a toothpick. "Our idea was to pack levitators close together, and then try to 'pass the ball' from one to the other," says Dr Daniele Foresti, who led the research.

To generate enough lift, the system blasts out sound waves at 160 decibels – about the same volume as a jet engine at close quarters. That's why the researchers use ultrasonic waves with a frequency of 24,000Hz, which is too high for humans to hear.

The acoustic levitator could allow scientists to move hazardous chemicals without touching them, handle cells without risk of contamination, and manipulate liquids that have been cooled below their freezing point. "Supercooled liquids tend to start freezing as soon as they touch a container," says Foresti. "By levitating them, we can keep them as liquids. For example, we could use our system to bring together two supercooled metals and create new kinds of alloys."

JAMES LLOYD



TIMELINE

The rise and rise of levitation research

1909

Dr Robert Millikan and Dr Harvey Fletcher at the University of Chicago levitate charged droplets of oil in an electrical field. Their aim was to measure the charge of an electron.

1971

At Bell Laboratories in the US, Dr Arthur Ashkin and Joseph Dziedzic use a laser to optically levitate glass particles. Versions of their 'optical tweezers' are used in research today.

1980

NASA develops an acoustic levitation system to simulate microgravity conditions, levitating objects such as a 5mm-diameter wooden sphere and a droplet of glycerine.

1997

Dr Andre Geim at Radboud University Nijmegen in the Netherlands famously levitates a live frog in a magnetic field, going on to win an Ig Nobel Prize for his efforts in 2000.



2006

Scientists at Northwestern Polytechnical University in China use sound waves to levitate small animals, including ants, ladybirds, beetles, spiders, bees and fish.

2013

Researchers at the Swiss Federal Institute of Technology in Zurich find a way to move objects and handle more than one at the same time using sound waves.

ANALYSIS

Bruce Drinkwater



Professor of Ultrasonics at the University of Bristol

“IT'S A LOVELY piece of work – they've got a superb level of control over the objects they're levitating. Levitation itself isn't a particularly new field, but in magnetic systems, the object has to have magnetic properties; in electrical systems, it has to be charged; in optical systems, it has to be transparent. Acoustic systems are much less concerned about the material that's inside them.

If you want to pick up larger objects, you'd have to increase the sound's wavelength. The wavelength is essentially the thing that grips the object. It's like your hand: you can pick up a tennis ball, but you can't pick up an atom or a house. In a similar way, the wavelength of the sound has to be comparable to the object you want to levitate.

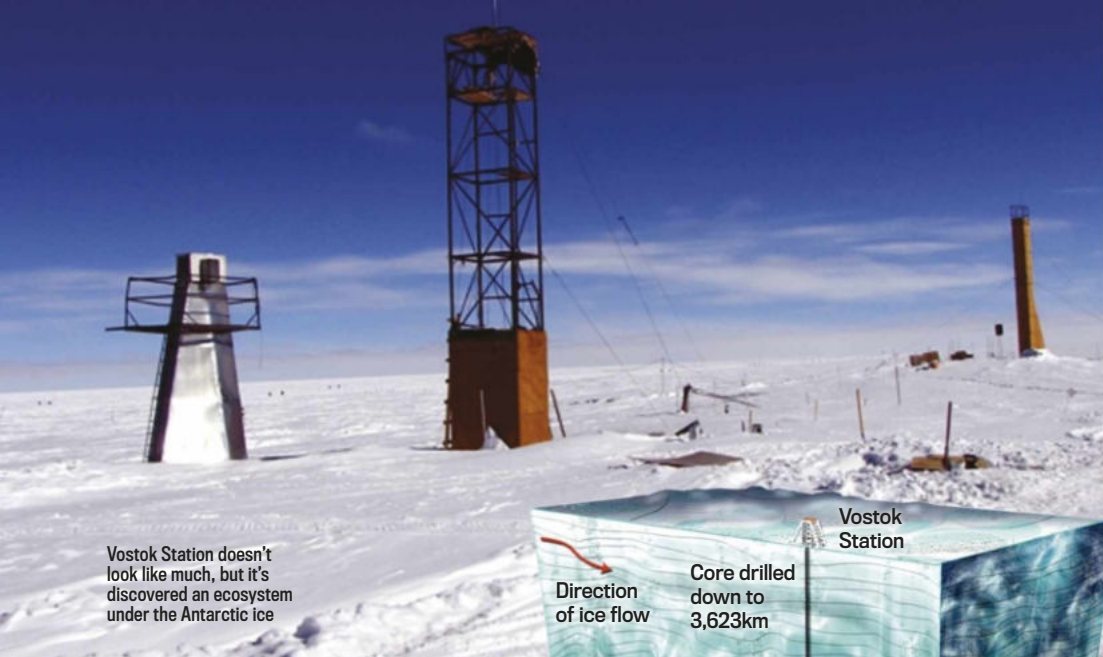
So to levitate a human, for example, you'd have to significantly increase the wavelength, decreasing the sound's frequency. That's a problem because it takes the sound waves into the audible range, which would be painful for humans. Also, extremely high sound power levels would be required, and we don't really know how the human body would cope with that.

I like the idea of a contactless production line that uses this technology, which could bring together electronic components or groups of cells in a sterile, hands-free environment.”



WHAT DO YOU THINK?

What do you think acoustic levitation should be used for? Let us know your thoughts at facebook.com/sciencefocus



Vostok Station doesn't look like much, but it's discovered an ecosystem under the Antarctic ice

Biology

Strongest signs yet of life in Antarctic lake

DESPITE BEING CUT off from the rest of the world for millions of years, there are strong signs that Antarctica's Lake Vostok is teeming with life. Samples of ice from just above the subglacial lake have been analysed, revealing traces of thousands of species. But researchers are stopping short of saying that this provides definitive proof of life in the lake.

Lake Vostok is the largest of hundreds of Antarctic lakes and is covered by 4km of glacier ice. Last year, Russian scientists succeeded in drilling down through to the lake for the first time, collecting water samples which are currently being analysed.

the lake froze. They have identified 3,500 unique genetic sequences. Most are from bacteria, though some belong to multicellular organisms. The research, published in the journal *PLOS ONE*, has led to criticism that the samples may have been contaminated.

"I don't think you can assure with 100 per cent certainty that you don't have some contamination," says Dr Scott Rogers, who was involved with the research. "[But] we used very stringent procedures, and just looking at the organisms that we had in our sample, I think it's nearly impossible that they could have come from contamination."

Earlier this year, life was discovered in another Antarctic lake, Lake Whillans, although that one is buried under just 800m of ice. Scientists searching for life on other planets, where the conditions may be similar to those in Lake Vostok, will take a keen interest in this new research. "Planetary scientists should be encouraged by what we've found," says Rogers.

HAYLEY BIRCH



In the meantime, biologists at Bowling Green State University in Ohio analysed a sample of 'accretion ice' extracted in 1998 that would have formed as

1 MINUTE EXPERT Optical lattice clock

What's that?

It's a new, super-accurate atomic clock that loses just one second every 300 million years.

How does it work?

Every clock keeps time by measuring some regular event. In a grandfather clock, it's the swing of a pendulum; in an atomic clock, it's the oscillations of atoms as they're bombarded by radiation. In the optical lattice clock, strontium atoms are vibrated using lasers. Their oscillations then provide an 'atomic pendulum'.

What could it be used for?

Since 1967, the second has been defined using atomic clocks that excite caesium atoms with microwaves. This new clock uses lasers to make strontium atoms vibrate at a far higher frequency, dividing time into much smaller intervals. This makes it around three times more accurate and could lead to a new definition of the second.

What's the point?

As well as redefining time, atomic clocks have plenty of practical uses. GPS satellites, for example, carry atomic clocks. Improving their accuracy could provide pilots, mountaineers and rescue teams with more precise information about their location.

WHO'S IN THE NEWS?



Professor Rowan Sutton

Director of Climate Research at the UK National Centre for Atmospheric Science, University of Reading

What did he say?

He's been talking about the fact that global warming has 'paused' in the last decade and a half, with no sign of the rapid global temperature rises seen in the 1980s and 1990s. "Some people call it a slow-down, some people call it a hiatus, some people call it a pause. The global surface temperature has not increased

substantially over the last 10 to 15 years," says Prof Sutton.

So what's behind this slow-down?

That's not clear. "Climate scientists absolutely expect variations in the rate at which the surface temperature will rise... but that is not to say we understand all the details of [temperatures over] the last 10

to 15 years," Prof Sutton has been quoted as saying.

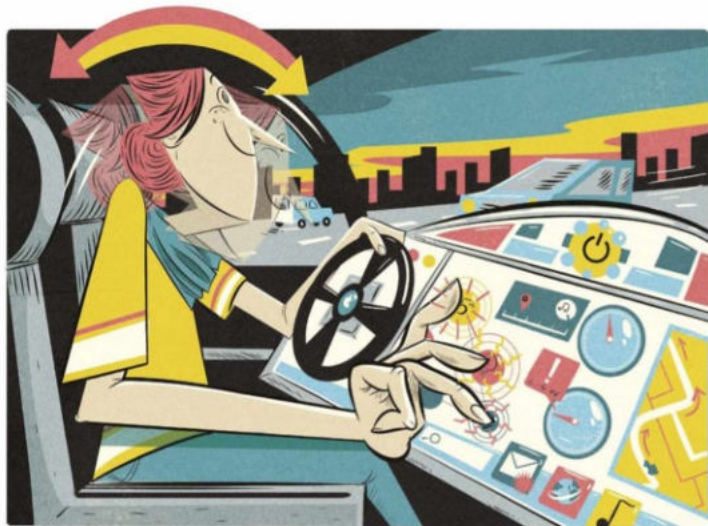
Are there any ideas?

The Met Office has produced three reports on the pause and says that levels of CO₂ have continued to rise, but the slow-down could be explained by the fact that some of the heat is being absorbed by the deep ocean.



PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd



Apple's digital dashboard

HAVING REVOLUTIONISED THE computers in our homes, Apple now wants to redesign the dashboards in our cars. The technology giant has come up with a 'Digital Dash' in which the usual cluster of knobs and dials in front of the driver is replaced with a large touchscreen.

But this won't simply be an iPad embedded in the dashboard. To keep the driver's eyes on the road, the tactile display will allow the driver to 'feel' whatever they're touching by sending pulses of

acoustic waves to their fingertips. The system may also include a head-tracking camera so the driver can nod up and down to make selections.

The patent, which has been granted, lists a plethora of possible functions that could be controlled or displayed on the screen. These include interactive maps, parking aids, voice access to email, an infrared night vision display, climate control, games for the passengers and even a maintenance screen featuring performance data and photos of key parts of the vehicle.

Patent number: US 8482535

The throwable camera

TAKING PHOTOS WITH a handheld camera is all well and good, but landscapes sometimes look a lot more interesting from the air. The Squito could be the answer. When this ball-shaped camera is tossed skywards, it can capture aerial shots of your surroundings.

Inventor Steve Hollinger in Boston, USA, came up with the design, which uses three cameras to take photos while it's airborne. Onboard orientation and GPS sensors tag each photo with the

ball's precise location and position and a processor then automatically rotates and stitches the shots together into one seamless panoramic image or fly-by video. This is then sent wirelessly to your smartphone, tablet or desktop.

But the Squito isn't just about improving your holiday snaps – it could also be used in emergency situations. The device could be thrown into an unstable building, for example, to scout for earthquake survivors. The patent application has been granted.

Patent number: US 8477184



Wrigley's new cooling sensation

TO GIVE YOUR mouth a chill, chewing gums use peppermint oil or menthol. But these can be too strongly flavoured, while other 'physiological cooling agents' taste unpleasant. Now Wrigley says it has found a compound, 'Gly-OiPr', which is neither minty nor unpleasant. This could lead to gums that offer a cooling effect from all sorts of flavours. Cooling toffee ice cream gum, anyone?

Patent application number: WO 2013096405 A1

Want to be a kid again? Just ask a Spanish psychologist



THEY DID WHAT?!

Adults given the body of a child

What did they do?

Using a head-mounted display and body-tracking suit, psychologists at the University of Barcelona

gave adults in a virtual world the body of a four-year-old child – or a child-sized adult body.

What happened?

The volunteers reported feeling ownership of their virtual bodies – an illusion that was shattered if the virtual bodies didn't mirror the movements of their real-life bodies well. The volunteers tended to over-estimate the size

of nearby objects, particularly if they had a child's body.

What does this mean?

The experiment was designed to test whether changing someone's self-perception alters their assessment of their surroundings – and it clearly does. It's a finding that will come in particularly handy for the designers of virtual reality games.



GREAT
LOOKING
HAIR
no fuss



Joe Hart

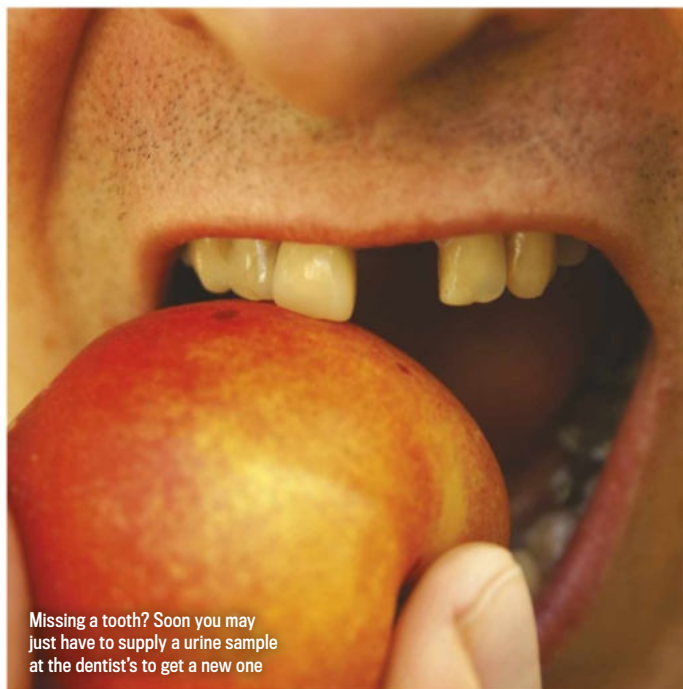
Joe Hart,
Goalkeeper



The 2 in 1 range deep cleans and conditions, giving you unbeatable dandruff protection[†] and hair that's more manageable. All in one bottle.

[†]Visible flakes seen at 2ft with regular use. ^{††}Among cosmetic anti-dandruff shampoos. ^{**}Winner Shampoo Category. Survey of 10,005 people by TNS.





Missing a tooth? Soon you may just have to supply a urine sample at the dentist's to get a new one

Health

Grow your own teeth... with urine

DENTISTS MAY one day be able to grow you a replacement tooth using a very unlikely source – your urine. Researchers in China have transformed cells discarded in urine into stem cells that can grow into tooth-like structures. The technique could provide a source of new teeth built from a patient's own cells.

Researchers led by Duanqing Pei, an expert in regenerative medicine at the Chinese Academy of Sciences in Beijing, harvested cells from human urine and then converted them into pluripotent stem cells – cells that have the potential to develop into any other cell.

These stem cells were mixed with molar dental tissue from mouse embryos and then transplanted into the kidneys of a different group of mice. After three weeks, tiny structures that resembled teeth had grown inside the mice's kidneys. What's more, their structure was similar to

human teeth, containing the central part of a tooth (pulp), the layer between the pulp and the enamel (dentin), and the hard surface (enamel). The researchers say that if human dental tissue was used instead of mouse tissue in the development process, the technique could, in theory, be used to develop a wholly human tooth bud that could be transplanted into the jawbone of a patient.

On the downside, the experiment only had a success rate of around 30 per cent and the artificial gnashers weren't as hard as real human teeth. "So far, the researchers have only been able to grow tiny teeth in mice," says Professor Anthony Hollander, Head of the School of Cellular and Molecular Medicine at the University of Bristol. "Functional human teeth need to be full-size and matured."

So, for now at least, we should be trying to preserve the set we already have.

JAMES LLOYD



CLICK HERE with Kelly Oakes

New websites, blogs and podcasts



CALBUG

www.notesfromnature.org/#/archives/calbug/

California scientists have thousands of bugs sitting in storage, with labels detailing when and where they were found. But without you, these creatures may never be

digitally catalogued. This citizen science project aims to create a database of over 1 million specimens that will help to pinpoint how these tiny creatures have been affected by climate change.

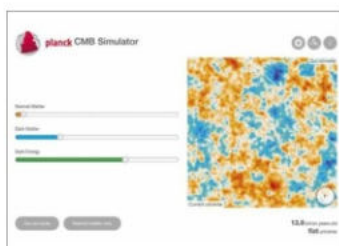


TED ED

www.youtube.com/TEDEducation

Here, some of the best educators and animators from around the world are brought together to make lessons you'll actually want to watch. From giant sea creatures, to dark matter

and big data, each video is a short, snappy and visually appealing look at one aspect of life, the Universe, and everything in it. You'll learn something, but you'll hardly notice.



CMB SIMULATOR

www.strudel.org.uk/planck/

This simulator lets you see what the Planck satellite's map of the cosmic microwave background would look like if the proportions of normal matter, as well as the other two more elusive components

of the cosmos, dark matter and dark energy, were different.

You can then see what fate – a big crunch or a big freeze – the Universe would meet with your chosen mix.



CODEBREAKER

<http://turinggame.sciencemuseum.org.uk>

War-time codebreaker Alan Turing would have been 100 last year and the Science Museum in London has an exhibition to celebrate the great man's work at Bletchley Park. But if you'd like to find out how you'd fare as a code cracker, look no further than these 10 challenges created by GCHQ. There are hints, but you won't make the leader board without going it alone.



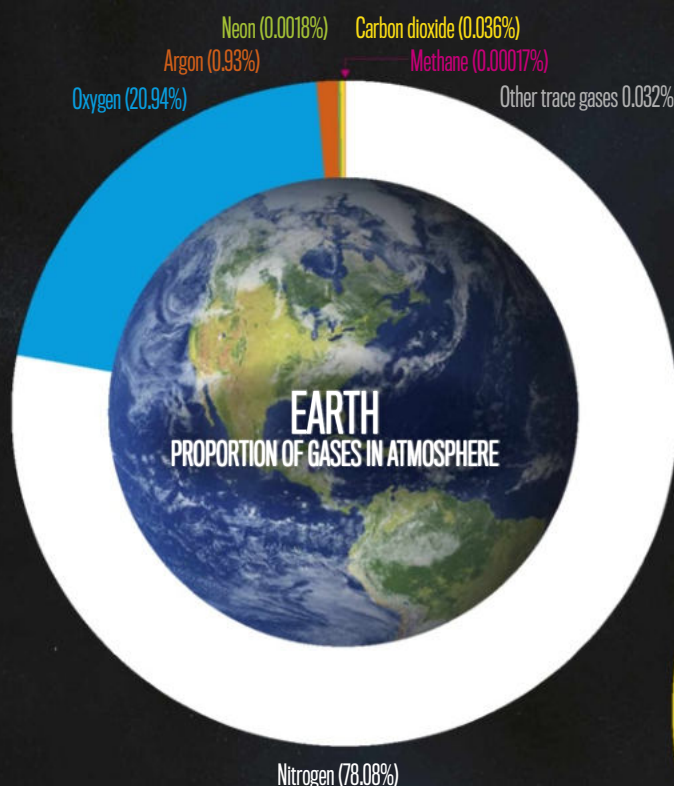
KELLY OAKES is a science journalist who tweets from @kahoakes



GRAPHIC SCIENCE

Seeing research differently

Curiosity kills the chances of life on Mars



EARTH
12,742km in diameter

MARS
6,779km in diameter



SINCE TOUCHING DOWN on the Red Planet at Gale Crater over a year ago, NASA's Curiosity rover has carried out the most accurate measurements of Mars's atmosphere – providing some intriguing insights.

It's strikingly clear that there's very little methane, indicating

that microbes – which would produce the gas – are unlikely to be present. This contradicts Earth-based measurements carried out in 2009 that suggested that three areas on Mars contain fairly high methane concentrations.

NEWS IN BRIEF

The brain's selling point

• The area of the brain that 'lights up' when we hear an idea we're likely to share with others has been identified. Psychologists at the University of California, Los Angeles found the brain's 'temporoparietal junction' was activated when participants heard an idea that they'd later recommend. This could prove handy to advertisers looking to determine which ads can go viral.

Extragalactic radio puzzle

• Astronomers have detected four mysterious flashes of radio waves from beyond the Milky Way. The bursts, which each last only a few thousandths of a second, were found in archived data from the Parkes Radio Telescope, Australia. Their cause remains a mystery, but one candidate is a magnetar. This is a type of neutron star with an intense magnetic field.

Human evolution in action

• Cholera may cause thousands of deaths a year, but the human body is evolving to fight back. The genomes of people from the Ganges River Delta region in Bangladesh, where the disease is rife, have been compared with people from northwestern Europe. Over time, cholera appears to be changing the genetic code of Bangladeshis so people are more resistant to it.



Inhabitants of the Ganges Delta are evolving resistance to cholera

Synthetic biology

Designer yeast will become chemical factory



Imperial College London is part of an international team synthesising yeast

AN ENTIRELY SYNTHETIC version of the yeast brewers use to make beer is to be created. The ultimate goal is to transform it into a chemical plant – producing chemicals on an industrial scale.

Teams around the world are creating synthetic versions of all 6,000 genes on 16 chromosomes that make up *Saccharomyces cerevisiae*'s genetic code and aim to have completed it by 2017, incorporating the DNA into living cells a year later.

A British team, led by Dr Tom Ellis at Imperial College London, has been given almost £1,000,000 government money to create chromosome number 11. It's a huge undertaking given the fact that its genes are made up of around two-thirds of a million base pairs – the chemical building blocks of DNA. But the work is already progressing well.

"In our lab, we've already replaced the first 50,000 base pairs of our chromosome with synthetic chromosome," says Ellis. "So what we have is a hybrid chromosome. It's a serial process – once you've done one 50,000 base pairs, you do the next and then the next." When the synthetic versions of all the

The yeast *Saccharomyces cerevisiae* could be the basis of a biotech revolution

chromosomes have been created, the international research team plans to design new strains of the yeast to produce useful substances such as vaccines and industrial chemicals.

The project's open source philosophy means other scientists will have access to synthetic yeast sequences and strains, allowing them to create their own designer organisms for whatever application they choose. "If you have a strain that can be grown in higher and higher concentrations of ethanol, it might be useful for biofuel production," says Ellis.

In 2010, US geneticist Craig Venter announced that his laboratory had built the first synthetic genome of a bacterium, *Mycoplasma mycoides*. Bacteria, which lack a nucleus, are known as prokaryotes. This yeast, the DNA of which is inside a nucleus, would be the first artificial eukaryote – the more complex organisms. The team includes scientists in the US, China and India.

HAYLEY BIRCH

HOT TOPIC

Should we be spending time hunting for aliens?

RESEARCH HUNTING FOR alien intelligence on distant worlds has been given a boost thanks to the formation of a new UK network that brings together experts in everything from astronomy to linguistics. The UK SETI Research Network (UKSRN) is made up of academics from 11 institutions and will consider methods for detecting signals from other planets and the linguistic challenge of deciphering messages.

Among the facilities being used is the e-MERLIN array of seven radio telescopes (pictured) that's spread over 217km, from Jodrell Bank in Cheshire to Cambridge. "We hope the network will excite interest from people in the UK astronomical community and encourage them to contribute their work," says Dr Alan Penny, co-ordinator of UKSRN.



WHAT DO YOU THINK?

Let us know your opinions at [facebook.com/sciencefocus](https://www.facebook.com/sciencefocus) and our forum at [sciencefocus.com/forum](https://www.sciencefocus.com/forum)



Richard Bull: I think Eleanor Arroway said it best when requesting funding for her SETI research project: "You're right, it's crazy. In fact, it's even worse than that, nuts... You wanna hear something really nutty? I heard of a couple of guys who want to build something called an 'airplane'; you get people to go in, and fly around like birds. It's ridiculous, right?"



Chris Arnold: It's one of man's oldest questions... we won't be satisfied if we don't keep looking.



Mr Isaksson: The scale of the Universe almost predicts that there has to be life. But the Fermi paradox is really troubling me. Why haven't we found some radio signal?



Lateralman: I would say from the very fact that there are billions of stars out there and we haven't heard a peep it proves that we are alone.



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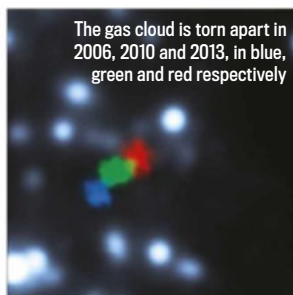
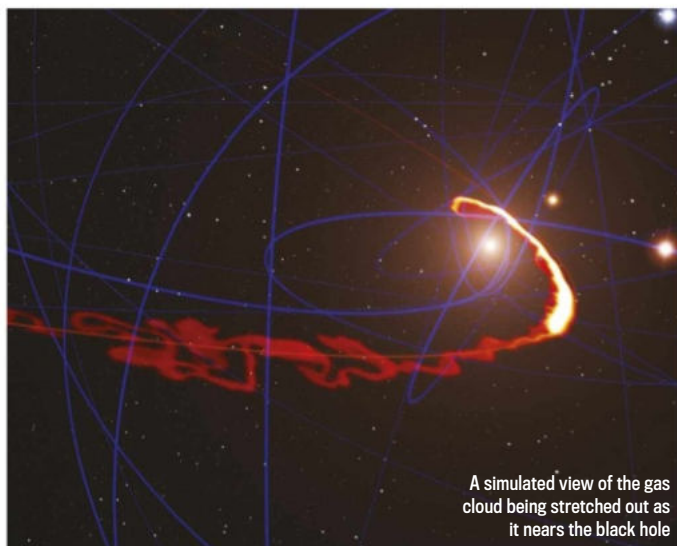
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*Test done in Dec 2010 by Stiftung Warentest.

Astronomy

Black hole tears up vast gas cloud



A VAST CLOUD of gas and dust has been observed being ripped apart by the supermassive black hole at the centre of our Galaxy. The cloud is being stretched by the black hole's gravity, providing a unique opportunity to understand more about this most mysterious of phenomena.

Astronomers using the European Southern Observatory's Very Large

Telescope (VLT) have been watching the cloud draw close to black hole Sagittarius A*. "Like an unfortunate astronaut in a science fiction film, we see that the cloud is now being stretched so much that it resembles spaghetti," says Stefan Gillessen at the Max Planck Institute for Extraterrestrial Physics in Germany, who led the observing team.

As the gas cloud is being stretched, its light gets harder to see. But the team has been able to measure the cloud's velocity by staring at the region close to the black hole. They took an exposure of more than 20 hours using the VLT in the Atacama Desert in Chile.

The front of the cloud, having passed the hole, is now moving back towards us at more than 10 million km/h. Despite the speeds involved the encounter, previewed in the June issue of *Focus*, will not be over quickly. "The cloud is so stretched that the close approach is not a single event, but rather a process that extends over a period of at least one year," says Gillessen.

Astronomers now watching events unfold round the world will be hoping to understand regions close to the black hole that have not been previously studied. They will also be trying to investigate more about the effects of incredibly strong gravity – after all, Sagittarius A* has a mass four million times that of the Sun.

ANDY RIDGWAY



WHAT THE PAPERS SAY

Henry Gee on the latest from leading journals

ALIEN LIFE IN YOUR HOME?

TWO NEWLY discovered viruses are the closest things anyone has ever come to encountering alien life forms on Earth. Indeed, the scientists behind the discovery of the intriguingly named pandoraviruses use the word 'alien' in their report in the journal *Science*.

Viruses are the ultimate parasites. Consisting only of a small amount of DNA packaged in a protein coat, they attach themselves to the surfaces of cells – it could be a bacterium, or, in the case of the common-cold virus, the cells in your nose – and inject their own contents into the cell. Once inside, they take over the cell's own biochemical machinery, hijacking it to make more viruses. Eventually the cell becomes a husk packed with viruses, which are released to spread their contagion to other cells.

Because viruses use their host's works to reproduce themselves, they don't need to have their own genes for feeding or metabolism, for dividing in two, or for many aspects of ordinary life. That's why most viruses only contain a few genes of their own. HIV-1, for example, the virus that causes AIDS, has just nine.

Of the many amazing things about pandoraviruses, two stand out. The first is that they are enormous. Most viruses are truly tiny – they have very few genes and can only be seen in an electron microscope. The scientific world was startled 10 years ago with the discovery of

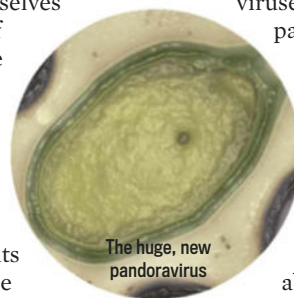
mimiviruses, which have around 1,000 genes. Pandoraviruses, though, are twice the size of mimiviruses, and seem distinct – they aren't just bigger mimiviruses. They have more than 2,000 genes – dwarfing some bacteria and even some more complex cells.

The second surprising fact is that more than 93 per cent of pandoravirus genes are completely different from any other genes so far described, in any organism – including other viruses. This suggests that

pandoraviruses have taken a completely different evolutionary trajectory from any other known organism. Either that, or it shows how little we know about the diversity of life around us.

Perhaps the most remarkable thing about the pandoraviruses, though, is that the researchers didn't have to trawl the bottom of the ocean or high mountaintops to find them – one was found in a pond, in Melbourne, Australia; another in marine sediment just 10m below the surface at the mouth of a river in Chile. Both kinds parasitize a species of amoeba also known to host mimiviruses.

Who knows what else remains to be discovered? Perhaps some completely unknown form of life lurks behind your sofa or on the soles of your shoes...



HENRY GEE is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*

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New research suggests that dinosaurs like *Ceratosaurus magnicornis* had warm blood like us

Biology

Dinosaurs weren't cold-blooded killers

THERE IS NEW evidence that dinosaurs were warm blooded like birds and mammals rather than cold blooded like reptiles, says an Australian physiologist. Professor Roger Seymour at the University of Adelaide has calculated that without the ability to generate their own body heat, they would not have had the strength to dominate their mammal competitors in the way they did.

Seymour has calculated the muscular power of the saltwater crocodile, which can reach over a tonne in weight and has many similarities with the conventional picture of dinosaurs. Among those

similarities is an inability to generate heat in their cells through burning food energy – in other words being cold blooded.

He found that a 200kg croc can only produce about 14 per cent of the muscular power of a mammal at peak exercise and this figure appears to decrease at larger body sizes. "Dinosaurs dominated over mammals in terrestrial ecosystems throughout the Mesozoic," says Prof Seymour. "To do that they must have had more muscular power and greater endurance than a crocodile-like physiology would have allowed."

ANDY RIDGWAY

Palaeontology

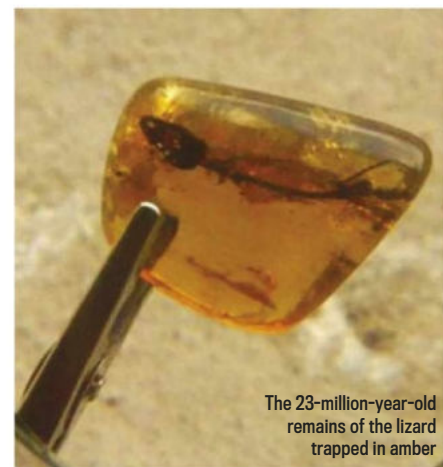
Age-old lizard perfectly preserved

THE BODY OF a miniature Mexican lizard has been discovered, enshrined in amber. While amber fossils containing plants and animals are relatively common, such well-preserved examples are rare. Thought to be around 23 million years old, it has survived the evolution of humans and many of our predecessors.

At just 1cm by 4cm, the reptile, found in Simojovel in southern Mexico, may be small but it's perfectly formed, retaining a complete skeleton and even bits of soft tissue and skin. Scientists at the National Autonomous University of Mexico, who estimated the lizard's age by dating its amber casing, think it may be related to anole lizards found in Florida today. Its modern day descendants are colour-changing lizards, sometimes sold as pets, that can measure up to five times the size.

The lizard is now on display at a nearby amber museum in San Cristóbal de las Casas.

HAYLEY BIRCH

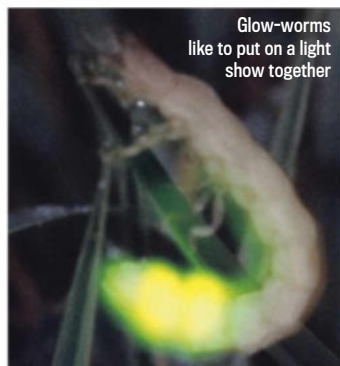


The 23-million-year-old remains of the lizard trapped in amber

NEWS IN BRIEF

Glow-worms unite

Like thousands of fairy lights lit up en masse, cave-dwelling glow-worms synchronise their glowing patterns to maximise the effect. Scientists at the University of Queensland in Australia found that glow-worms matched each other's cycles of luminescence, with the overall brightness peaking during the day. This strategy may help them attract and catch prey.



Glow-worms like to put on a light show together

Obesity's mind control

People who carry a version of the FTO gene are more likely to be overweight, but now we know why. Research led by University College London reveals that people with this gene have high levels of the hunger-stimulating hormone ghrelin, even after a meal. When these people were shown pictures of food after eating, the reward centres in their brains were active.

A monster star is born

Astronomers using Chile's ALMA telescope array have discovered a monster star in the process of forming in our home Galaxy. The embryonic star currently sits within a dark, swirling cloud of gas and dust, which is expected to collapse into a star up to 100 times more massive than our Sun. The stellar birth will help astronomers find out how such mammoth stars form.



INSIDE SCIENCE

ROBERT MATTHEWS

Computer software is putting people in power – not conventional voting

CAN YOU FEEL the excitement? Are you agog at the prospect of seeing our politicians perform at this month's party conferences? No, me neither. I know I should: after all, these are the people who decide what our taxes are spent on and what laws we must abide by. I certainly care about all these things, and I'm hardly alone in that. I'm bored with politicians. Whether left or right, centre, green, or monster raving, it makes no difference – they don't seem to really care what we think. Which is odd, given that politicians rely on our votes for their continued employment.

But something has changed in recent years. Our politicians, not known for being numerate, let alone tech-savvy, have become heavy users of computational psephology. From the Greek word for 'pebble' (which they used to vote with), psephology is the study of elections. Which sounds really boring until your future depends on it, as it does for politicians – and, as a consequence, ours does too.

Indeed, just scrape the surface of the democratic process and you'll find a host of fascinating paradoxes. Mathematicians started studying them over 250 years ago, and now our politicians rely on them to win elections without being remotely popular.

These paradoxes undermine all the standard voting systems. Take the one used by the UK and many other democracies, 'first past the post'. Imagine an election where all the candidates are pretty much equally rubbish, so around one-third of the electorate actually

vote (typical for MEP elections). Those that do vote can lumber the rest of us with a candidate even most of them didn't want with the seat being won with, say, just 31 per cent of the vote, the next biggest getting 29 per cent, the other 40 per cent being spread among the other candidates. The end result: total victory for a candidate who won by just 2 per cent, and whom barely 1 in 10 of the electorate actually wanted. If that's democracy, I'm Genghis Khan.

It's a demonstration of what mathematicians call non-linearity, in which just small differences are amplified into huge effects. And the bad news is that politicians are getting very good at exploiting these non-linearities in voting systems to turn small numbers of voters into huge electoral power. All the major parties now use computers to help win 'key marginals' – seats that can be won by convincing just a handful of voters to switch parties. Such seats make up barely 10 per

“Key marginals make up barely 10 per cent of seats in the UK, which explains why you're being ignored”



cent of all seats in the UK – which explains why you feel you're being ignored by politicians. You are: they're too busy sucking up to the mathematically far more important voters in key marginals.

To do it, the parties use data mining computer software to analyse reports from canvassers across the constituency to find out which issues resonate with voters. The software then generates leaflets, posters and 'pitches' for candidates to use on the doorstep. It's not exactly clever stuff, but that's the point: non-linearity ensures small things count for a lot.

So is there anything we can do to get our voices heard? Sure: make smarter use of technology ourselves. It's already happening. Social media sites like 38 Degrees are allowing voters to get colossal e-petitions dumped on Downing Street in hours, compelling ministers to listen to our concerns about issues like health reform. Then there's 'vote-swapping', where those of us stuck in safe constituencies can use social media to find others happy to vote for us in seats where our vote would matter, in exchange for us doing the same for them.

Politicians are keen to perpetuate the myth that the ballot box is the only route to a strong democracy. It isn't – and the more e-petitions, emails and tweets they receive telling them so, the better. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

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EVERYDAY SCIENCE

HELEN CZERSKI

The life of a plastic ball: a journey through the aeons of time

DON'T TOUCH THAT", came the strict parental instruction. "You don't know where it's been!". The child sadly put the object back down on the beach and toddled off in search of more acceptable fun. I walked over and looked down at the cause of the fuss. It was a small plastic ball, grimy from exposure to the weather. I didn't know for sure where it had been either, but I stopped and thought about it. I reckon that it's likely it had been on some adventures. Something a bit like this...

Imagine a tropical sea, at a latitude near 25° North. It's hot and humid, and the peace is only disturbed when a plesiosaur whooshes past, hunting squid. The nearest land is some way away, and it's covered in ferns, conifers and horsetails. Stegosaurus roams the land and pterodactyls fly overhead. This is the Jurassic.

The sunlight pouring into the sea is feeding algae and bacteria, which are the start of a huge food chain. Most of them are eaten by tiny marine animals, which then become fish food. But they're messy eaters, and they never quite clean their plate. Some of the algae and bacteria live to die a natural death, and then they sink, slowly. At the bottom of the ocean, they settle; this is a muddy cemetery. The ocean currents are sluggish, and there is no oxygen, so the newcomers don't decompose. They sit. More sand and corpses settle on top.

The continent drifts north, carrying the sea with it. This sea is now the focal point of a continental tug of war, and the centre of it sinks as it's stretched by forces that can build and destroy mountains. Massive earthquakes shift the sediment, which is now very thick. Our algae are buried 4km deep, where it's about 120°C. The molecules that make them up are finally giving in to the temperature and the pressure. They change shape to form long chains: hydrocarbons. The tug of war shifts to another rift valley. When this second valley opens up, it forms the Atlantic ocean. An asteroid hits, pushing the dinosaurs into the past. But that doesn't matter deep below the floor of the North Sea, where the algae and bacteria are slowly being cooked until they transform into oil.

The age of the reptiles is over and the age of the mammals begins. The oil starts another journey. The pressure in the deep rocks is intense, and so the oil migrates upwards, meandering slowly through tiny pores in the rock. It might travel many hundreds of metres upwards. Eventually, it meets a rock layer too solid to travel through, and it stops.

Humans have evolved. The North Sea has reached 50°N, where it is today. A few ice ages come and go. The Roman Empire, the

"What was Jurassic algae is now polyethylene. Someone makes the polyethylene into a ball..."



The history of our planet is encased in a plastic ball you might play with on the beach

Vikings and the Industrial Revolution sweep past. Someone drills down through the rock trapping the oil, and when the oil reaches the surface it's touched by sunlight for the first time in 150 million years. It's processed to form the raw ingredients needed for plastic, and then with a bit of chemical help, the short carbon chains join together. What was Jurassic algae is now polyethylene. Someone makes the polyethylene into a ball, and not long afterwards, a child on a beach turns his back on it.

We don't normally think of something as mundane as plastic as

having a romantic past, but I don't think it gets much better than this. Next time you see a piece of plastic, pick it up and be amazed by where it's been. ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose shows include *Operation Iceberg* and *Orbit*

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FOCUS
SCIENCE AND TECHNOLOGY

HOW SLEEP CAN
MAKE YOU SMARTER

By careful manipulation of your slumber, you can turn it into the ultimate cognitive enhancer

Words: Dr Penelope Lewis

PEOPLE DO ALL kinds of things to get ahead in today's competitive world. The struggle for jobs and promotions is cut-throat, and the use of performance-enhancing drugs such as Modafinil and Ritalin is on the rise. But ironically, nature's best cognitive enhancer is often entirely overlooked.

What makes you feel great when you have it and a complete basket case when you miss out? That's right – sleep. Something we should all spend roughly one-third of our time doing, but which we actually tend to squeeze at both ends, with tiredness and underperformance the result.

But sleep is not only critical for staying alert and attentive. We're now beginning to understand the extent to which it influences our ability to learn new things – everything from riding a bike to learning Spanish. And this new understanding is showing us how we can use sleep to enhance our memories.

The idea that sleep and memory are linked is nothing new. Back in 1924, two American psychologists, John Jenkins and Karl Dallenbach at Cornell University, enlisted a pair of

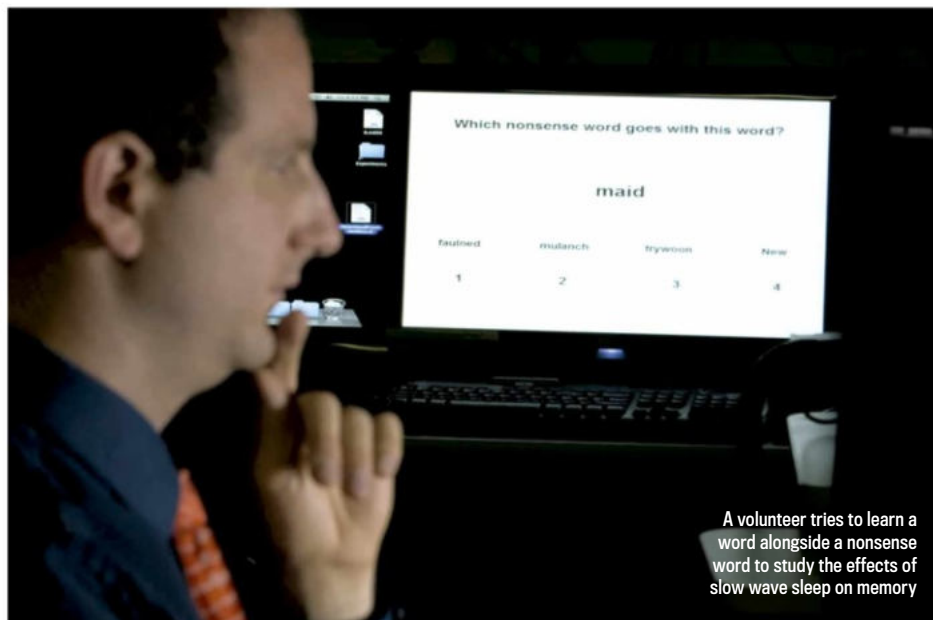
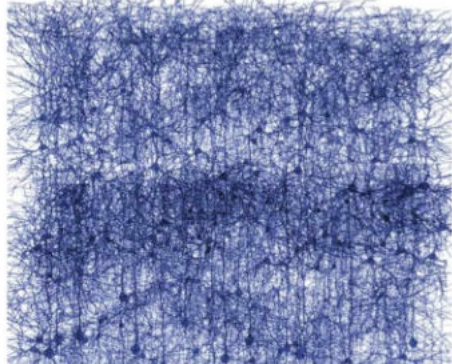


“Sleep can work wonders with our ability to learn motor skills - from riding a bike to typing faster”

→ students to learn nonsense syllables. The researchers then tested the students' memories one, two, four and eight hours later. What they found was that students could remember more of the syllables when they had been to sleep between the learning session and the test than when they had been awake. In other words, sleep had somehow improved their memories.

But it was only when we started to understand the different phases of

The microcircuitry of the neocortex, which stores memory fragments, can be seen as a forest of neurones



A volunteer tries to learn a word alongside a nonsense word to study the effects of slow wave sleep on memory

sleep – different stages in our slumber characterised by a different depth of sleep and different patterns of electrical activity in our brain – that we started to fully grasp exactly how sleep affects memory. What became clear is that the different phases consolidate different types of memory.

MORE NONSENSE

Earlier this year, researchers at the University of California carried out some research with echoes of that performed by Jenkins and Dallenbach almost 100 years earlier in that the participants were asked to learn nonsense. A bunch of young adults – whose average age was about 21 – and a group of older adults – whose average age

was about 75 – were instructed to learn word pairs consisting of real words, such as ‘birds’, and made-up words, such as ‘jubu’. They found that both the younger and older participants were able to recall the pairings better the more ‘slow wave sleep’ (SWS) – characterised by a slow pulsing of brain activity – they had at night (see ‘Phases of sleep’, on p37).

Another piece of research that was perhaps a little more traumatic for its participants proved that sleep also helps us remember events that fire our emotions. A group of students at the University of Bamberg in Germany were given emotionally charged texts to read, such as one that detailed the killing procedures of a child murderer. When the students were only able to sleep over the second half of the night, so they had more ‘rapid eye movement’ (REM) sleep, they were much better at recalling details of the text than when they had non REM sleep (in the early part of the night) or no sleep at all.

Sleep can also work wonders with our ability to learn motor skills – anything from riding a bike to typing faster. Neuroscientist Dr Matthew Walker, then at Harvard Medical School, trained people to tap a complex series of keys on a computer keyboard and tested them 12 hours later. Those who did not sleep between the two sessions improved their performance by two per cent, whereas those who did were 20 per cent quicker without a loss of accuracy. This type of memory forming seems to occur during a lighter phase of sleep called stage two NREM.

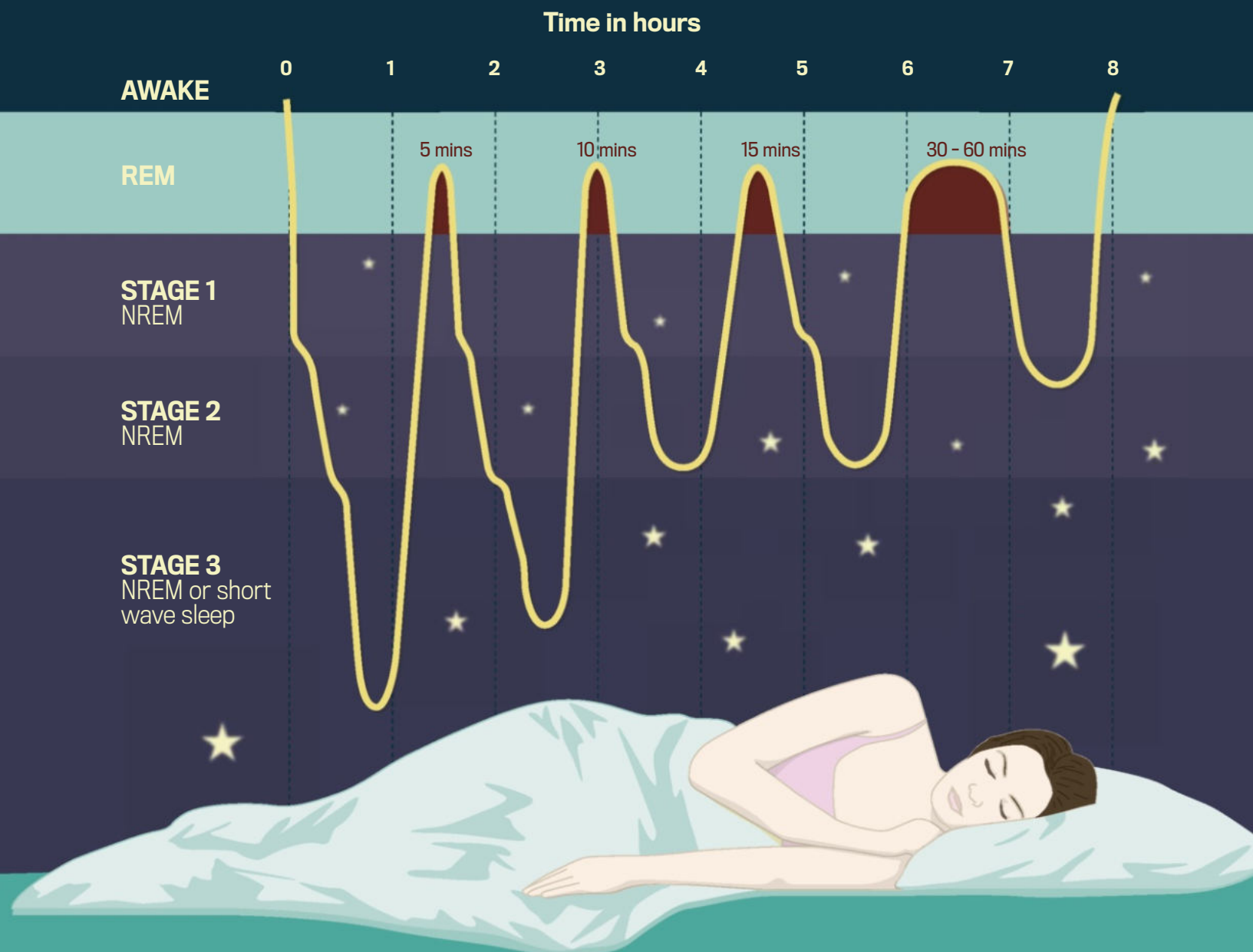
But how does sleep achieve all this? One answer relates to memory replay. We know from recordings of brain activity that the patterns our nerve



Dr Matthew Walker has found that sleep can help you learn practical skills

PHASES OF SLEEP

The brain typically cycles through four sleep stages in the same order every 90 minutes – the amount of time spent in each varies across the night



NON-REM SLEEP (NREM):

As you move through these three stages, activity in the brain gets slower and slower, and your brain's neurones fire in greater and greater synchrony.

Stage 1 NREM

People awoken from this stage often believe they have been awake. They don't remember falling asleep. It's during this phase that we experience hypnic jerks – involuntary twitches.

Stage 2 NREM

This makes up the majority of our sleep. Dreaming is less common than in deeper stages and the sleeper is easily awakened.

Stage 3 NREM or short wave sleep (SWS)

This is the deepest stage of non-REM sleep. EEG readings show high-amplitude slow oscillations in electrical activity (there are big differences between the peaks and troughs of the graph), reflecting the fact that

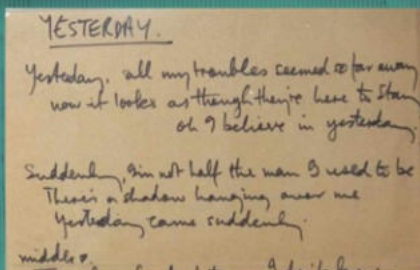
many neurones in the brain are acting in synchrony.

Rapid eye movement sleep (REM)

You may already know this as the stage most associated with darting movements of your eyes under closed lids and emotional dreams. In contrast to SWS, the different areas of the brain are not synchronised but are instead each 'doing their own thing', just as they would when we're awake.

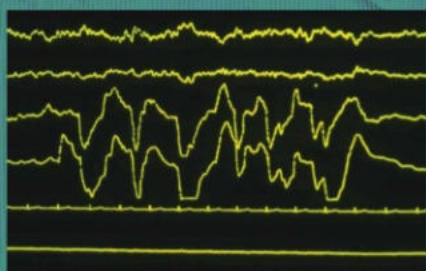
5 THINGS YOU DIDN'T KNOW ABOUT SLEEP

We all do it, yet it's still full of surprises



1. REM SLEEP BOOSTS CREATIVITY

During REM sleep the concentration of neurotransmitter acetylcholine is twice what it would be when awake. This promotes the altering of connections between neurones, facilitating new links between disparate pieces of information. The Beatles classic *Yesterday* (pictured) and *Frankenstein* are said to be products of sleep.



2. DREAMS PERVADE OUR SLEEP

The idea that dreams only occur in REM sleep (EEG reading pictured) simply isn't true. We actually have dreams throughout all stages of sleep and even when we're awake, as daydreams. However, it is fair to say that dreams are more common in REM than non-REM sleep as well as being more vivid, emotional, and bizarre.



3. SLEEP DEPRIVATION IS AN ANTIDEPRESSANT

Sleep deprivation leads to a sort of semi-euphoric state and has been used to treat depression since the early 1970s. Unfortunately, low mood often returns as soon as the patients are allowed to get some sleep. It also has to be used with caution as a treatment - prolonged sleep deprivation leads to impaired working memory and other health problems.



4. OUR SLEEP REQUIREMENTS VARY WIDELY

Measures of alertness by testing reaction times have shown big differences in how much sleep we need. In research carried out at the University of Pennsylvania, eight hours did the trick for most people, helping them to maintain their reaction times. But an estimated 5 per cent of the population, including, famously Margaret Thatcher, can get away with five hours or fewer.



5. THERE IS AN EXCUSE FOR LATE NIGHTS (FOR SOME)

Early to bed, early to rise doesn't suit everyone - research has shown that some people are genetically predisposed to stay up later at night and get up later in the morning. For roughly 40 per cent of us, this is the optimum pattern, and we will feel better and be more productive if we stop trying to force ourselves out of bed at 6am.

"Need to memorise Spanish? Try an intense study session in the late afternoon, followed by a SWS-filled nap"

→ cells or 'neurones' fire in when we're learning during the day are frequently replayed when we're asleep. It's as if the brain carries out a rehearsal.

In slow wave sleep, there's a synchronised firing of millions of neurones in the neocortex - the outer part of the brain. These slow pulses of electrical activity have been found to determine when other neurones can fire, ensuring that memory replay occurs at the same time across all of the relevant brain structures. So if you're recalling a meeting with a friend, it might ensure the visual and auditory cortices replay her face and voice at the same time so they match up.

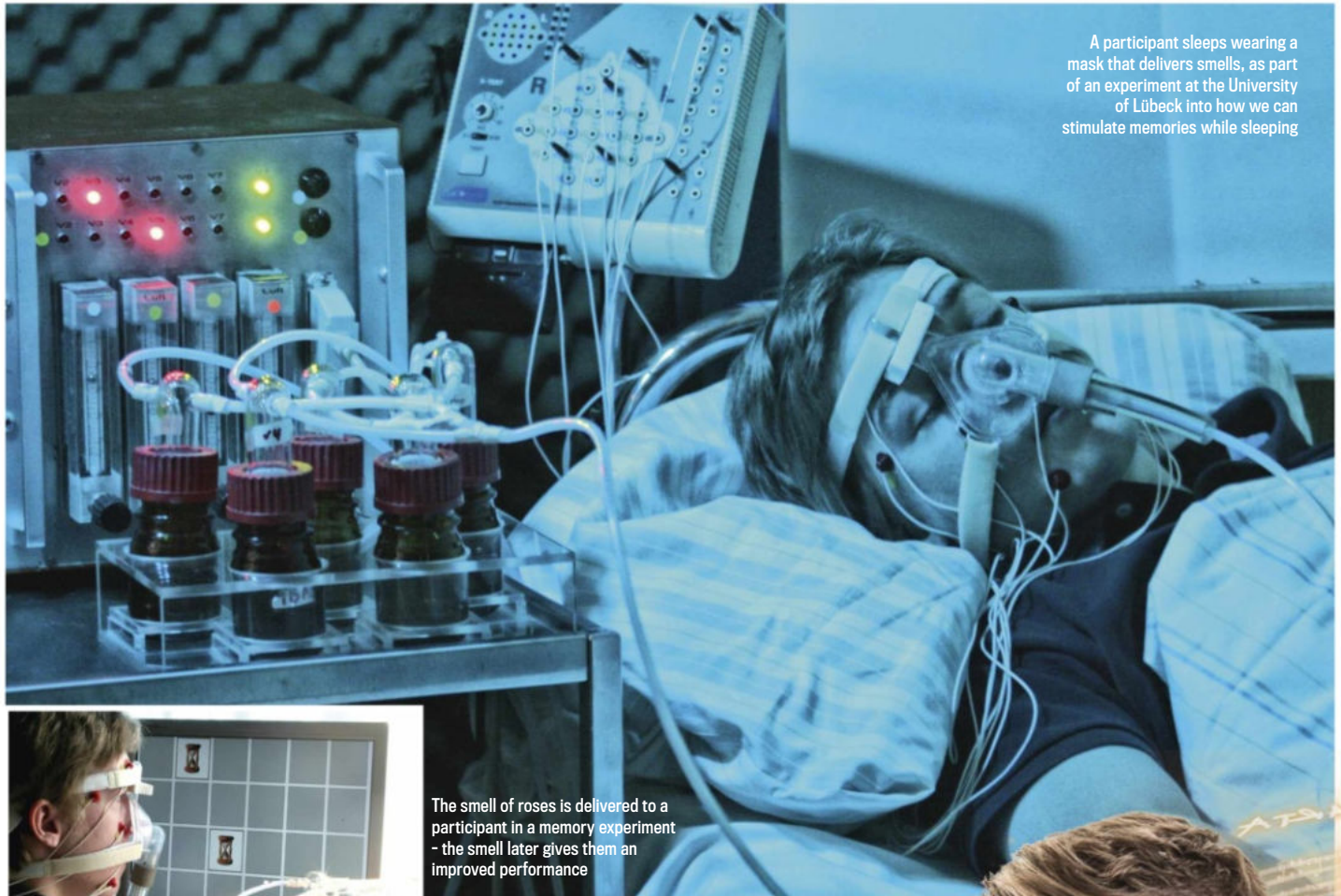
This co-ordinated replay is thought to strengthen memories just as it would if you mentally rehearse something while you're awake. As neuroscientists say, 'neurones that fire together wire together'. Concurrent neural activity strengthens the connections between the neurones involved, shoring up the physical basis of the memory.

SLEEP TO REMEMBER

But it isn't just the replaying of memories that underpins sleep's memory magic. Sleep's various stages are associated with dramatic changes in the levels of neurotransmitters - chemical messengers that carry or modulate signals between neurones and other cells in our bodies.

Acetylcholine, which plays an important role in keeping the brain awake, drops to half its normal concentration during SWS. This may help to strengthen individual memories, since low concentrations are thought to promote the transfer of information from a fragile short-term storage network that relies heavily on the hippocampus deep within our brains to a more robust long-term storage system that instead depends upon neocortical areas.

Of course, there's a big catch to all of this. On the face of it, we don't have much choice about the proportions of the



different sleep phases our brain obtains in a typical night. Nor do we choose which memories are replayed and strengthened. So how can we use sleep as a cognitive enhancer? The answer is that we actually have a lot more control over these things than you might think.

Sleep is locked to the circadian cycle, the natural 24-hour rhythm of our bodies, and you're likely to get more REM in the morning and more SWS in the afternoon or evening. This means strategically planned naps can help to ensure you get the kind of sleep you want. Need to memorise a load of Spanish vocabulary? Try an intense study session in the late afternoon, followed by a SWS-filled nap. Want to remember a highly emotional wedding or christening? A nap in the morning should help out with a super-duper dose of REM.

As well as controlling the phases of sleep, we can also cause specific memories to be replayed when we've nodded off.

Sleep researcher Björn Rasch at the University of Lübeck in Germany asked volunteers to play a game. An array of matched card pairs were spread out 'face down' on a computer screen. They were then tasked with flipping up one card and trying to remember the other card that matched it. The volunteers played this game several times until they had a good memory of where every card was. While doing this, the smell of roses was wafting in their noses. After playing the game, everyone had a normal night of sleep before a retest the next day. Some people were exposed to the rose smell again before sleeping, some during SWS, and some during REM.

Interestingly, the people who smelled roses again during SWS improved more than any of the other participants. The same trick works with sounds – but just make sure they are played softly so you don't wake up!

Exciting new developments have shown that we might be able to take even more direct control over our sleep phases in



THE POWER OF DREAMS

Our in-sleep experiences and memories are inextricably linked

HAVE YOU EVER noticed that your dreams contain memories? Some scientists suggest that dreams may actually be indicative of the memory replay that takes place when we're asleep and is important for memory consolidation. They hypothesise that only some elements of a replayed memory, the tip of the iceberg, make it into consciousness and these are manifest as dreams.

Evidence supporting the link between dreams and memory includes the observation that people tend to improve at new skills more if they dream about them. Dr Erin Wamsley, Associate Professor Bob Stickgold and colleagues at Harvard Medical School found that undergraduate students who had dreamt of a computer game maze they had earlier been challenged to learn, improved more than those who had slept but didn't dream of the game.

The memories we experience in dreams are usually fragmentary – a face, a place, an image. Only rarely do dreams replay a complete scenario that was experienced. This could be because only a small part of the memory being replayed reaches



The steroid cortisol, pictured here as crystals, gradually builds up and disrupts your brain from recalling memories while you sleep

awareness, but it could also be because specific aspects of sleep physiology prevent the various elements of a memory from being bound together. The most coherent memories occur during the more mundane dreams of non-REM sleep early in the night – it was this sleep that the Harvard students were experiencing. Memories that happen during the vivid dreams that characterise REM sleep, a phase that increases through the night, are much more fragmented.

There's a possible reason for these increasingly fragmented memories. A steroid called cortisol builds up gradually across the night. When the levels have become high during the early morning REM sleep, it disrupts communication between the neocortex, which stores individual memory fragments, and the hippocampus, which helps to bind these together to form complete memories. This also explains why our morning dreams can often be bizarre.

➔ future. Professor Lisa Marshall, again at the University of Lübeck, has found that if an electrical current is injected into the head at the same frequency that this firing normally happens in SWS – just a little slower than once a second – it produces the rhythmic activity in the brain that even continues after the current has been switched off.

Although technically fake, this 'stimulated' SWS dramatically improves memory consolidation. But not everyone will feel comfortable about having their brain artificially stimulated in this way. The good news is that researchers at both Lübeck and Wisconsin have found that simply playing tones at the right frequency while asleep has a similar effect.

People who take Modafinil or Ritalin should be drooling at natural ways to boost the brain. But they aren't the only ones who would benefit. As we age, the amount of SWS we obtain in a night declines. By 75 or so, many of us will get none at all.



Importantly, it's been found that the greater the decline in SWS, the greater the cognitive decline and some scientists believe the absence of this critical sleep stage may be a factor in the further degeneration of the brain. If this is the case, then the artificial stimulation could be a panacea for older people, helping to restore their SWS and stave off further cortical ageing. Who knows, we could all be getting a dose of sound therapy while we sleep to keep our minds sharp in old age. ■

DR PENELOPE LEWIS is a lecturer in neuroscience at the University of Manchester

Find out more

The Secret World Of Sleep
by Penelope Lewis
is on sale 27 August
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HOW TO BUILD A PLANET

As data on planets from the farthest reaches of our galaxy comes to light, **Govert Schilling** draws up a blueprint for a habitable world

The planets in our Solar System are an orderly bunch. They move in the same plane, and they orbit the Sun in the same direction. In the mid-18th Century, German philosopher Immanuel Kant first drew the obvious conclusion: the planets must have formed in a flat, rotating disc of material surrounding the newborn Sun.

Today, astronomers know that such 'protoplanetary discs' are common. Moreover, hundreds of exoplanets – planets orbiting other stars than our Sun – have been found that tell the story of early planetary formation. So what have we learned about a planet's birth? And how easy is it to build habitable worlds like our own Earth? ➔



Accompanies the BBC series *How To Build A Planet* with Richard Hammond

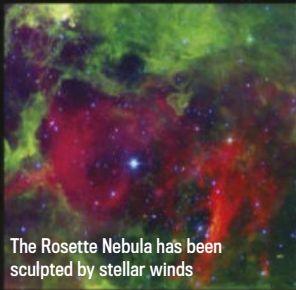
BBC ONE



COLLAPSE A CLOUD

To build planets, you must create stars first. But that's easy, since gravity does most of the work. Take a large cloud of cold molecular gas, sprinkled with cosmic dust. Any composition will do. Then let Nature do its job. The cloud collapses under its own gravity, clumping into smaller globules in the process – something like the dust in your house gathering together under your bed. Conservation of angular momentum (think ice skaters who spin faster when retracting their arms) and centrifugal forces (think a thrown-up rotating clump of dough changing into a thin, flat pizza) turn each mini-cloud into a flat, rotating disc, surrounding a nascent sun. Hey presto, there's your protoplanetary disc.

That said, to this day Hubble is still throwing up data that's making scientists reconsider the parameters within which planets are able to form. Earlier this year, the telescope discovered evidence of a planet orbiting 12 billion kilometres from its parent star – that's twice as far as Pluto is from our Sun.



The Rosette Nebula has been sculpted by stellar winds

PROTECT DELICATE DISCS

Fledgling protoplanetary discs are vulnerable. If you want them to spawn planets, don't let them be blown away. According to recent observations by space telescopes working at infrared wavelengths, this could easily happen in a crowded stellar nursery like the Orion Molecular Cloud. Newborn massive stars pump out huge

amounts of ultraviolet light and produce fierce stellar winds. These winds can blow cavities in the cloud and erode everything in their way, including the planet-forming discs around low-mass stars. After all, there's not much to these discs, which typically contain just one per cent of the mass of their stars. So stay away from the cosmic action. A quiet environment is the place to be!

“To this day, Hubble is still throwing up data that's making scientists reconsider the parameters within which planets are able to form”

Planets orbiting two stars might be rare



BEWARE OF BINARIES

Binary stars are planet killers. Yes, NASA's Kepler space telescope has recently discovered 'Tatooine planets' with two suns in the sky, like the home planet of Luke Skywalker in the *Star Wars* movies. But although binary stars are very common in the Milky Way, the evidence from computer simulations suggests that such

'circumbinary' planets are probably rare. "Pairs of stars may truncate protoplanetary discs through gravitational disturbances," says Dimitar Sasselov of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.

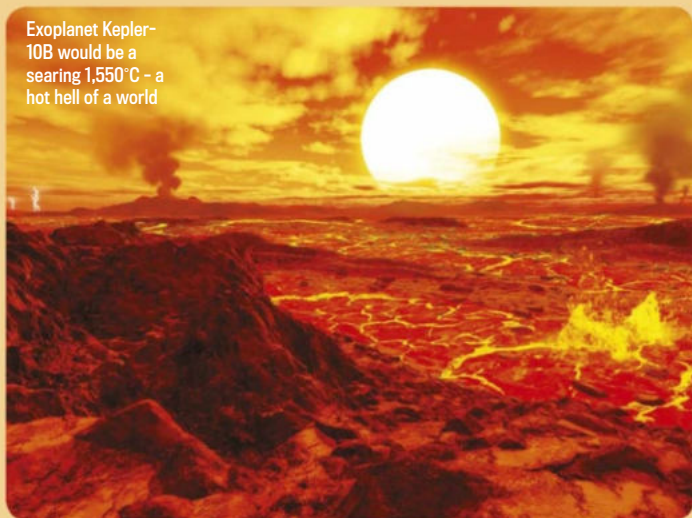
In other words, a stellar couple can be too clingy. Single stars make for better parents.



THE PLANET ZOO

Planets can come in all shapes and sizes... and that can have major implications for their chances of hosting life

Exoplanet Kepler-10B would be a searing 1,550°C - a hot hell of a world



MOLTEN MARBLE

Extrasolar planet Kepler-10B, announced in January 2011, was the first 'Earth-like' planet found by NASA's Kepler space telescope. It's only 40 percent larger than our home planet, and from its high density, astronomers deduce a metal/rock composition. But at a mere 2.5 million kilometres from its Sun-like parent star, the planet must be cooked up to a temperature of some 1,550°C, and its hellish surface is probably a churning ocean of molten lava.

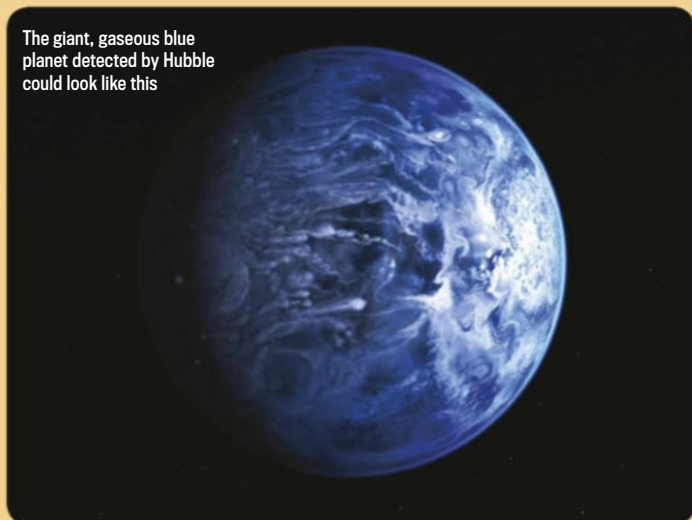
An artist's impression of the 'super-Earth' GJ 1214B, which could be a water world with aquatic life



WATER WORLD

GJ 1214B is an exoplanet that's almost three times the size of the Earth, but far less dense. With an overall density of less than 2g per cm³, it is almost certainly a water world, with a relatively small rocky core surrounded by a thick mantle of water and an equally thick, steamy atmosphere. Despite its high surface temperature of some 200°C, this stripped-off 'mini-Neptune' could potentially harbour simple aquatic life forms.

The giant, gaseous blue planet detected by Hubble could look like this



HOT JUPITER

Exoplanet HD189733B is a 'hot Jupiter' orbiting a bright star every 2.2 days. It's one of the promising exoplanets studied so far: astronomers have detected water vapour, oxygen, methane and carbon monoxide in its atmosphere. Recent Hubble observations have revealed the planet to be azure blue, thanks to the light-scattering properties of silicate particles in the atmosphere. Meanwhile, the star's fierce radiation is causing the giant planet to slowly evaporate: every second, it loses some 10,000 tonnes of gas into space.

Aurorae circle the pole of the planet PSR B1257+12A as it's bathed in X-rays from its parent pulsar



BATTERED BARREN

PSR B1257+12A is a strange beast. It's one of three planets orbiting a pulsar - the small, compact corpse of a massive star that went supernova. The planet is only twice the mass of our Moon, and almost certainly has a rocky composition. The pulsar planets may have formed in the aftermath of the supernova explosion. They're constantly battered by the high-energy X-rays of the pulsar - no single living cell could survive this cosmic ordeal, so there's no chance they could harbour life as we know it.

→ SUPPLEMENT WITH SOLIDS

For planet formation to start, your disc must contain solid particles that can clump together – either microscopic motes of silicate dust and iron filings, or frozen crystals of molecules like water, methane and ammonia. The more elements heavier than hydrogen and helium the disc contains, the larger your planets can grow. Close to the star, particles accumulate into dust grains, pebbles, boulders, asteroids and rocky planets. Further out, icy particles grow into frozen comets and, eventually, planetary cores that attract thick gaseous envelopes from the original disc to become Jupiter-like giants. Just stir and wait.

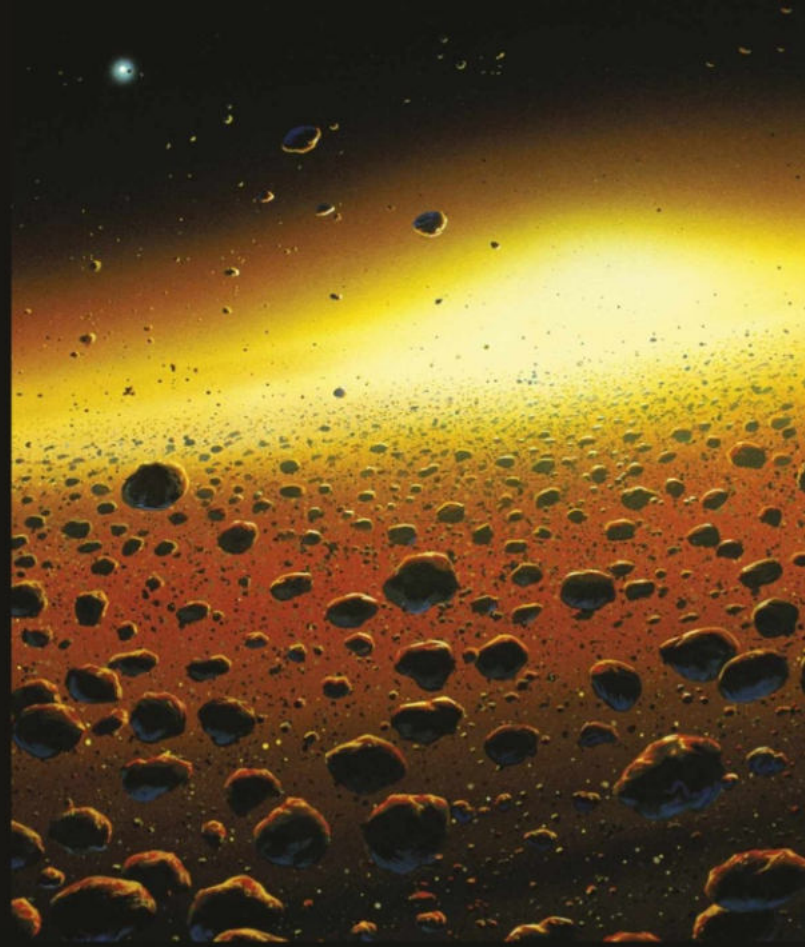


Planets coalesce out of dust surrounding a star

TRAP THE DUST

Simulations show that millimetre-sized particles are slowed down by the gas in the disc and spiral inward. But if you want these dust particles to gather into chunks, something needs to trap them. Fortunately, observations carried out with the ALMA telescope in Chile have revealed the existence of just such traps in the disc of a

15-million-year-old star, probably due to differences in gas density.



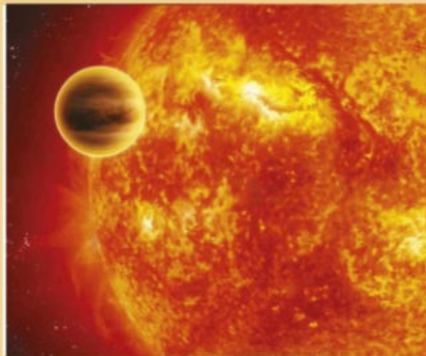
PLANET HUNTING – A STORY OF SURPRISES

The relatively short history of planet hunting has thrown up many surprises and often led us to wrong conclusions about how worlds are formed. Here are three discoveries that changed what we thought we knew about planets



HOT JUPITERS

The first extrasolar planets to be found turned out to be very different from the planets in our own Solar System. They were at least as massive as Jupiter, and they orbited their parent stars at distances of only a few million kilometres. Was this the galactic norm? Certainly not. In fact, hot Jupiters are pretty rare, but since they produce the largest and fastest wobbles in the motion of their parent stars, they stand out like sore thumbs. Hot Jupiters are in fact thought to be outnumbered by their rocky counterparts.



HEAVY METAL

A decade ago, it looked like stars with a relatively high fraction of 'metals' (the astronomical term for elements heavier than hydrogen and helium) in their outer layers were more likely to have a retinue of planets. Surely a metal-rich star must have been accompanied by a metal-rich disc, containing loads of planetary building material? But again, this only turned out to be true for the stars harbouring hot Jupiters. Astronomers now know that planets can and do exist around stars with widely varying amounts of metals.



SOLAR SYSTEMS

So far, no single exoplanetary system has been discovered that closely resembles our own Solar System. But that's by no means an indication that we are unique in the Universe. Systems with small planets in the inner regions and massive planets further out are exceptionally hard to detect using the equipment and techniques that we have available to us today. There could nevertheless be millions of them out there, awaiting discovery with future instruments and space telescopes.



It could take hundreds of thousands of years for dust particles to start to clump together into larger objects around a star

LOOKING FORWARD



Dimitar Sasselov, director of the Harvard Origins of Life Initiative, discusses what exoplanet science might discover next

IMMANUEL KANT'S BASIC idea with planets forming in circumstellar discs turned out to be spot-on. "We've encountered many surprises," says Sasselov, "and frankly, the idea of planet-spawning discs could have been one of the things to fall by the wayside. But it didn't. Discs rule."

We also now know that the basic mode of giant planet formation is the 'core accretion' model. Smaller particles first accumulate into solid, icy planetary cores, which then bind huge amounts of gas to them to form Jupiter-like worlds. The alternative 'disc instability' model,

where dense swirls of gas collapse into a planet in one fell swoop, appears to be exceptional.

Still, there are many questions about planetary formation that remain unanswered. For instance, no-one knows the critical minimum mass a planetary core must achieve before it can grow into a full-fledged gas giant. The existence of giant planets at very large distances from their parent stars – such as the HR 8799 system – is also hard to explain. "We now know that planets are fairly easy to build. But there are still a lot of interesting things to work on," says Sasselov.

Planets can get smashed by gas giants migrating towards the star



COPE WITH MIGRATION

Even giant planets may migrate inward due to interactions with the remaining disc. These cases end up as 'hot Jupiters', racing around their parent stars at distances of only a few million kilometres. So would a rocky world in the inner parts of a planetary system survive a giant planet passing through? Maybe not, admits Sasselov, "but migration

occurs in about a million years or so. Small planets may condense in the remaining disc after giant planets have passed through."

Moreover, he adds, hot Jupiters are very rare. Then again, there's also group migration, which leads to small, compact multi-planet systems like the ones surrounding Kepler-11 and Gliese 667C.

A planet has to be the right distance from its star to have liquid water



CHECK THE BAKING

If you have succeeded in cooking up an Earth-sized planet, make sure it's what you expected it to be. Instead of a dense, rocky planet with a massive core of iron and nickel, it may actually be a watery, low-density mini-Neptune, with most of its hydrogen 'jacket' stripped off after it migrated closer toward its parent star. For Earth-sized worlds,

astronomers don't know the fraction of low-density versus high-density planets, says Sasselov. To find the answer, you also need to measure their masses, which is difficult. "But the number of small planets, especially around red dwarf stars, is way higher than we anticipated," he says. "Even if a large fraction of them turn out to be water worlds, the number of Earth-like planets must be huge."

"There are many questions about planetary formation that remain unanswered"

A world needs heat to give life a kick-start



KEEP WARM

With a bit of luck, your planet ends up in the 'Goldilocks zone' of its parent star – the region where temperatures are just right for the existence of liquid water. For red dwarf stars – where planets are plentiful, according to Kepler data – this comfort area is closer in than for hotter stars like our Sun. But if you've succeeded in

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GOVERT SCHILLING is an astronomy writer. Asteroid 10986 Govert is named after him

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THE RESURR OF EGYPT'S LOST CITY

Archaeologists are bringing Heracleion, an ancient port frozen in time at the bottom of the Mediterranean Sea, back to life

Words: Matthew Symonds Images: Christoph Gerigk

FOR CENTURIES THE only physical evidence of the ancient Egyptian city of Heracleion was a handful of mentions in ancient texts. In its heyday, at the end of the era of the pharaohs, it was said to be an incredibly wealthy port, acting as the gateway to Egypt. It was even said to have been visited by Helen of Troy before being lost beneath the Mediterranean Sea around 1,200 years ago.

While few scholars doubted that Heracleion once existed, it was far from clear if it would ever be found. But in 2000, it was rediscovered some 6.5km from the modern Egyptian coast. Today, archaeologists are finding tablets, gold coins and huge statues that had been hidden for centuries, and which show how important this port would have been.

Finding this lost city was not easy. The ancient texts placed Heracleion, also known as Thonis, near Alexandria at the mouth of the Nile as it opened into the Mediterranean. But anyone seeking it faced a trail that had long gone cold.

Franck Goddio, president of the Institut Européen d'Archéologie Sous-Marine, was not deterred. With the aid of the French Commission of Atomic Energy, he developed a custom-built nuclear resonance magnetometer to search the seabed off the Egyptian coast. The magnetometer detects objects by the disturbances they create in the seabed's magnetic field, and in 1999 Goddio found something. At Aboukir Bay, on the north coast of Egypt, there were faults in the clay sediment – a sign of the disaster that destroyed the city.



EXCAVATION



Divers inspect the remains of a 5m-tall statue of an unidentified 4th Century BC pharaoh. It's believed to have stood at the entrance to the great city temple.

WHERE WAS HERACLEION?

Its position at the mouth of the Nile brought it wealth

At the time it was founded in the 8th Century BC, Heracleion was located at the mouth of the River Nile. Today it is 6.5km off the Egyptian coast. Heracleion's status diminished after nearby Alexandria was founded in around 331 BC. More conveniently located to capitalise on trade with the west, this new port city also lay on a natural limestone ridge – a far more stable environment than the Nile silts that doomed Heracleion.



➔ Heracleion and neighbouring Canopus – an ancient Las Vegas infamous during the Roman era for its debauchery – were built on a thin layer of silts capping waterlogged clay. One suggestion is that a tsunami added to the pressure exerted by major buildings, forcing the water out of the clay and bringing a sharp drop in ground level. As the ground level dropped, the cities above were lost. Whatever triggered the collapse, this was a disaster waiting to happen – the unstable substrata that formed the foundations of these cities meant they were doomed from the outset.

HIEROGLYPHIC PROOF

While science had led the exploration team to the lost city, it could not positively identify the site. The only way to prove that this was ancient Heracleion was to send down divers.

"In the first year we found part of an inscribed chapel that belonged to the main city temple," says Goddio. "On it was written in hieroglyphics that this temple was dedicated to Amun-Gereb. We know that this was the God worshipped in Heracleion. Finding this proof was an extreme pleasure."

With Heracleion identified, underwater excavation began and the University of Oxford's Centre for Maritime Archaeology (OCMA) was invited to study the artefacts being discovered. Over time, the Oxford team has also become involved in the excavations.

"It has all the fun of a normal dry-land excavation with none of the tedious removal of spoil," says Dr Damian Robinson, director of the OCMA. "We have to get through about 50cm of mobile sand, and we do that using a water dredge." This tool works by pumping water down a hosepipe from a support ship into a 4m-long plastic tube. The water is injected midway along the plastic tube's length before being ejected out of one end. This movement of the water creates suction at the other end of the plastic tube, allowing it to suck up the sand.

"Visibility is really poor," says Robinson. "Some days you'll see a few metres, other days you'll see a few centimetres – and this is in a submerged city covering around 2km²." But despite the poor visibility, the team has managed to capture some stunning images of the archaeology on the seabed. Many of these photographs show statues and stelae – or inscriptions – found within the ruins of the ➔

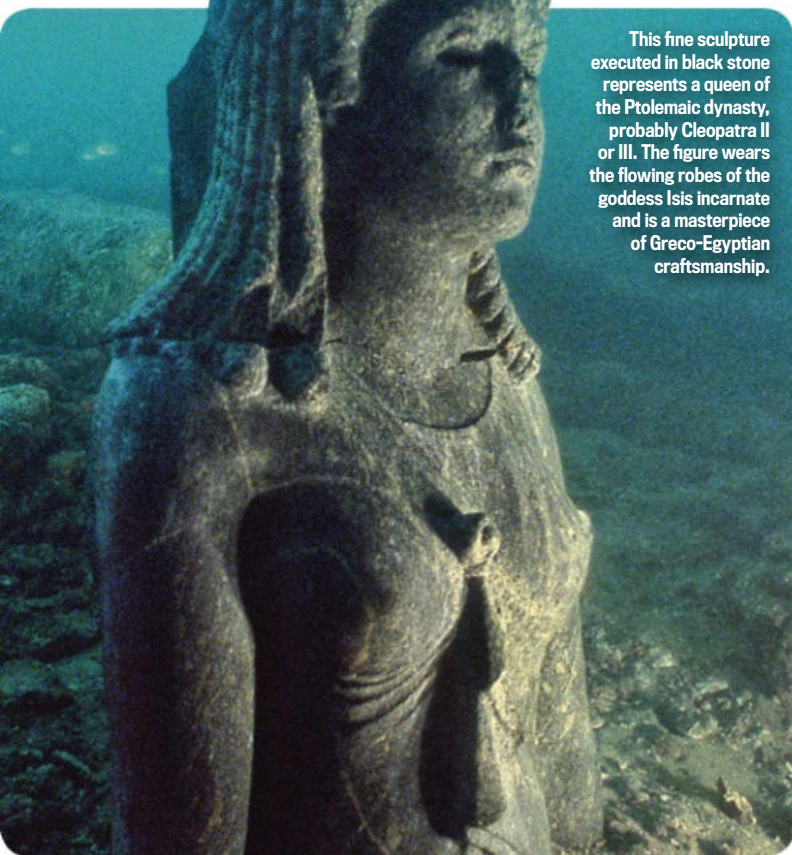


- ➊ A diver measures the feet of a red granite statue.
- ➋ The Triade of the main temple of Heracleion, raised and laid out on a barge. The pharaoh, his queen and the god Hapi are all depicted in statuary, together with a large stele (stone slab used for commemorative purposes).
- ➌ A bronze statue of Osiris, the king-god. The open eyes are depicted in gold leaf.
- ➍ The 5.4m-tall statue of Hapi that resided in the temple.

This monumental stele is known as the Decree of Saïs and was positioned near the main temple. It records that pharaoh Nectanebo I, reigning from 378-362 BC, granted 10 per cent of import tax to the priests of Neith. The stele shows the goddess Neith seated while Nectanebo furnishes her with gifts.



This fine sculpture executed in black stone represents a queen of the Ptolemaic dynasty, probably Cleopatra II or III. The figure wears the flowing robes of the goddess Isis incarnate and is a masterpiece of Greco-Egyptian craftsmanship.



The city's destruction has preserved a range of metal objects that were often melted down and reused elsewhere. This Hellenistic lamp dates to the 2nd Century BC and was found within the ruins of the temple of Amun-Gereb.



A CITY REBUILT

Digital reconstruction of Heracleion shows the temple at its heart

At the height of its prosperity, the city occupied an area of roughly 2km by 1km. But by the time it was destroyed most of the population had left, leaving the urban area little more than a hollow shell.

The main city temple of Amun-Gereb. A magnificent monument 150m in length, its entrance was flanked by 5m-tall statues of a 4th Century BC pharaoh and his queen, while the god Hapi stood to one side.

Heracleion owed its wealth to its location at the gateway to Ancient Egypt. The city grew fat off customs duties levied on boats entering the Nile.

Huge stelae – upright slabs with inscribed surfaces – were erected near the temple. One, the Decree of Saïs, gave 10 per cent of import tax to the priests of the goddess Neith on the orders of Pharaoh Nectanebo I.

Different types of anchor point to the presence of boats from many regions including Greece and Phoenicia, a civilisation centred on modern Lebanon. The wrecks of 64 boats and ships lie in the former harbour.

➔ main city temple. This complex was the lynchpin of urban life. "The temple was huge," says Goddio. "It was 150m long and lay at the centre of social and economic life. Food was redistributed to the inhabitants here and it was the site where customs levies were raised on all boats entering Egypt. So this temple was both rich and powerful."

HAPI HOME

"We have a good idea of the architectural form of the temple. At its entrance was a row of statues: the pharaoh and his queen. There was also a figure of the god Hapi, symbolising the flooding of the Nile, which was linked to wealth and wellbeing. Hapi must have been of particular importance to this city at the mouth of the Nile, as this is the largest statue of him ever discovered. Usually his statues were small, but this sculpture stands 5m high."

These colossal carvings of the pharaoh, his queen and the god Hapi are among those raised by the archaeologists for more detailed study. So far, nearly 100 statues and sculptural fragments have been recovered from the deep. Hundreds of smaller statuettes and large



A diver discovers the head of a dark stone statue of an unknown Ptolemaic queen. Egyptologists believe the statue is most likely a depiction of Cleopatra II or III, dressed in the robes of the goddess Isis.



A diver examines a red granite statue of a queen of the Ptolemaic dynasty. Dating to the 4th Century BC, the sculpture stood 4.9m high and could have been paired with an equally colossal statue of a pharaoh. Together they probably flanked the main entrance to the temple of Amun-Gereb.



This beautiful bronze statuette was found lying in silt near the temple of Amun-Gereb. Topless and wearing a crown, the figure is a miniature representation of a pharaoh of the 26th dynasty, which ruled Egypt from around 685-525 BC.

numbers of more modest artefacts including coins, pottery and lead objects have also been brought to the surface, many of which are being studied by researchers from Oxford.

More statues may be forthcoming from a major new discovery at the site. "Last year we discovered evidence of another main city temple, to the north of the other. It dated from the 8th Century BC to the 4th Century BC. So there were two main temples at Heracleion. The first was destroyed by a natural disaster – just like the rest of the city over 1,000 years later – and so it was simply rebuilt to the south. There was so much wealth to be made here that no-one wanted to abandon the site."

NEW DISCOVERIES

As the archaeologists prepare for this year's excavation season in September, techniques including sonar will determine what gets excavated. With sonar, pulses of sound are sent underwater from a boat on the surface, interesting archaeology revealing itself as anomalies in the resulting echoes. "We are led by the magnetometer and sonar surveys," says Goddio. "They tell us where to excavate. At the

current rate, I think that the work at this city will go on for centuries. I hope so."

When Heracleion's final reckoning came in the 8th Century AD, the city's golden age was already far in the past. Never regaining its hold over Egypt's maritime trade after Alexandria blossomed, Heracleion's inferior location left it withering away. At the moment of collapse, it was "no more than an archaeological site – a city that had already been abandoned," says Robinson. "It's not like Pompeii being destroyed by Vesuvius in AD 79, it's more like the ruins of Pompeii being destroyed today."

That the settlement had fallen on hard times does not make it any less valuable to archaeologists. "The city is amazing because it is an emporium, a port where the Greek, Persian and Egyptian worlds connected," says Robinson. "You can see in the pottery and even in the style of the anchors where all these people were coming from and the nature of the trade they were engaged in. It's just a phenomenal site." ■

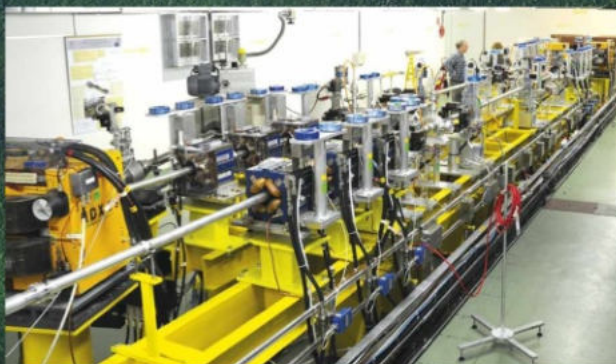
MATTHEW SYMONDS is the editor of *Current Archaeology* magazine

SUPER SMASHER

The Large Hadron Collider at CERN is the largest experiment ever built. Now meet its successor, a mega-machine that will delve even deeper into the fine structure of the Universe

JUST OVER A year ago, on 4 July 2012, physicists at CERN near Geneva celebrated the discovery of the Higgs boson – an elementary particle that endows others with mass – at the Large Hadron Collider (LHC). Even before the champagne was put on ice, however, scientists were already plotting a successor to this monster machine that would study the Higgs in greater detail. Something with more finesse was needed. The LHC is a bit like smashing two oranges (protons) together just to watch the pips (quarks) collide – it gets a bit messy. So while finding the Higgs boson marks only the beginning of the LHC's work, it's not so well equipped to study the Higgs itself – and any other particles it discovers – in fine detail.

Now, after 20 years of development, physicists have released the blueprint for the LHC's successor. Named the International Linear Collider (ILC), it will accelerate bunches of electrons and their antimatter partners, positrons, before smashing them together. As the ILC uses smaller particles, the collisions are much cleaner than the LHC's and scientists will be able to measure the Higgs boson's properties and how it interacts with other particles. Funding for the \$8bn, 33km-long collider has yet to be secured but Japan is already making moves to host it. Here's a look inside this future Higgs factory...



A test area at CERN, which is helping to develop equipment for the ILC



An experimental test beam for the ILC is set up at CERN

Magnets accelerate particles along tunnels

When completed the ILC will accelerate particles along 33km of tunnels with cooling stations every 5km to ensure it doesn't overheat

1 PARTICLE PRODUCERS

If you want to collide particles then first you have to produce them. The ILC will create billions of electrons by shining laser light onto a semiconductor made from gallium arsenide, ripping out billions of particles from the material. Positrons are made by passing the beam of electrons through a magnet that forces the particles to give off high-energy gamma rays. These rays are then shone onto a thin titanium-alloy target, producing pairs of positrons and electrons. Using magnets, the positrons are then drawn up into a beam.

2 FOCUSING BEAMS

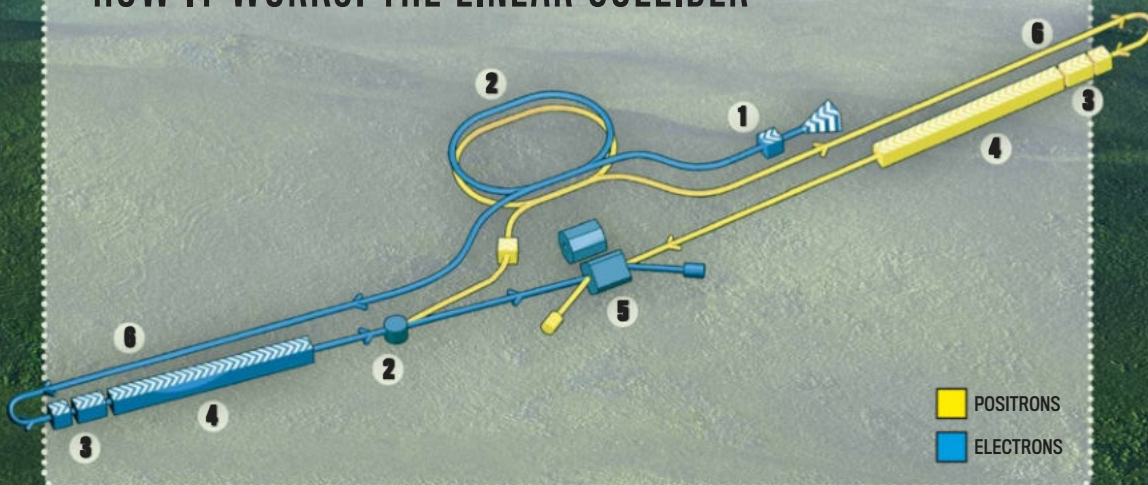
The electrons and positrons produced tend to be spread out very thinly over a length of about 9cm, giving the beam a very small density – not great when you need to increase the chance of collision. The ILC will use two 'damping rings' – one for electrons, one for positrons – that house a series of magnets called 'wigglers'. Beams passing through these wigglers are sent on a serpentine course, which reduces the size of the particle bunch. The beam that emerges is like a flat, thin ribbon just 6mm in length.

3 HEAVY COMPRESSION

While the electron and positron beams emitted from the damping rings are neatly packaged they are still not good enough. So a 'compressor' of magnets, shrinks the length of the beams further from 6mm to 0.3mm – the width of a human hair. At this stage the bunches also undergo their first acceleration, from 5 to 15 billion electronvolts – an energy that is equal to around a billionth of a calorie. This process produces ultra-compact bunches that are then ready to be accelerated to high energies and collided.

HOW IT WORKS: THE LINEAR COLLIDER

Not to scale



4 ACCELERATION

The star of the show at the ILC is the 'superconducting' technology. Around 8,000 1m-long superconducting cavities will accelerate the electron and positron beams from 15 to 250 gigaelectronvolts (GeV). Made from solid niobium, the cavities have a mirror finish and will be cooled to -271°C . At this temperature they become superconducting, meaning that they have almost no electrical resistance. An electric field then propels the electrons and positrons, each time increasing their energies.

5 DETECTING COLLISIONS

As the electrons and positrons reach 250GeV they come together, annihilating in a burst of energy and creating an array of new particles. It's these new particles – their interactions, lifetime and energy – that the detectors will study. The ILC includes two huge particle detectors, each weighing thousands of tonnes. Both detectors are designed to track particles produced by the collisions and measure their energies, but each detector is slightly different – the idea being that each machine will crosscheck the other's data.

6 COOLING DOWN

The ILC's magnets will be cooled by thousands of litres of liquid helium to reach temperatures below -270°C . The particle smasher will require one of the world's largest refrigeration plants to make liquid helium by compressing huge volumes of helium gas under intense pressures. To cool such a huge machine there will be 10 such cryogenic plants, located in pairs at 5km intervals along the ILC.

MICHAEL BANKS is news editor of *Physics World* and has a PhD in condensed matter physics

7 MYTHS ABOUT CATS

Are they really that curious and can they read your mind? Surprising new finds suggest it's time to forget what you think you know about your feline companion

WE ALL THINK we know our cats. They are often portrayed as wily, self-interested creatures that do precisely what they feel like doing. But cats are no more self-interested than any other animal – evolution quickly sidelines those who don't look out for themselves. And in fact, recent discoveries by molecular geneticists, veterinary scientists and animal behaviourists have overturned much of what we thought we knew about this familiar animal. So, if you think your cat is a calculating mind-reader beyond your control, you're in for a surprise...

DR JOHN BRADSHAW is Director of the Anthrozoology Institute at Bristol University and was an expert on the BBC programme *The Secret Life Of The Cat*



PHOTO: THINKSTOCK

01

CATS CAN'T BE TRAINED



THE SURPRISING TRUTH is that cats are just as good at learning as dogs are, so it should be possible to train them, although few people do. Partly this is because the cat's traditional function, hunting and killing vermin, comes naturally to them, and they are actually more successful at this when left to their own devices. Untrained dogs, on the other hand, are more of a hindrance than a help.

However, the fundamental difference behind the two species is not in how good they are at learning, but in what motivates them to learn. Dogs (*Canis lupus familiaris*) are unique in that they find human attention rewarding in its own right. They focus almost obsessively on what their trainers are doing. It means their behaviour can be shaped by following a desired behaviour with a pat on the head, say, or ignoring them when they do something else instead. Dogs can, of course, also be trained using food as a reward, but for most cats (*Felis catus*), this is the only reward that will work

consistently. Indeed, the easiest trick to train a cat to perform is to 'beg' for its food, as countless YouTube videos attest.

To train a cat requires a great deal more patience and perseverance than for a dog. This is because most cats only attend to people when they need something specific, while dogs do this all the time. They first have to be taught that there will be a payoff for paying attention, specifically a tasty prawn or morsel of chicken breast. Training sessions need to be kept short to begin with, since cats will walk away as soon as they get bored, and any attempt to drag the cat back to the training area will make it less likely to learn.

Training can be a valuable way of improving the cat's wellbeing at the same time as making life easier for the owner. For instance, a trip to the vet can be something of a trial. But if the cat has been trained beforehand that going in and out of its carrier is fun, and that the carrier itself is a safe and comfortable place to be, the whole process can be completed with a great deal less stress.



02

CURIOSITY KILLED THE CAT



THIS OLD SAYING implies that cats are so inquisitive that they regularly put themselves at risk, but in fact very few cats act like this. They do indeed vary in how inquisitive they are – a few are bold enough to approach novel situations, but most are generally much more circumspect, choosing instead to inspect anything unfamiliar from a safe distance. Biologists now consider that character traits like these are akin to human personalities and are common to many animals, not just cats.

It seems that when resources such as food are scarce, bold animals do better than timid ones because they get to eat first. However, being timid when approaching food also means that an animal is less likely to end up as a meal for a predator. This is how both personality types persist in a species.

So if the saying isn't true, how did it arise? It turns out that the original form of the saying, first recorded in the 16th Century, was 'care killed the cat' – care in the sense of worry or stress. Quite

why this was then considered notable is unclear, but veterinary science is now rediscovering the truth behind it. Many of today's pet cats suffer from stress-related illnesses such as cystitis and dermatitis, and recent research has shown that antagonistic relationships between cats are a major, perhaps *the* major, contribution to many episodes of these illnesses.

Stress can arise between cats in the same house, where the owner has unwittingly selected two that do not get along, or between cats in neighbouring houses fighting over a boundary between their respective territories. Cats lack the sophisticated analysis of body-language that enables dogs to resolve such differences and can live in a *state* of conflict for months, even years, on end. A typical example of this was shown on the BBC *Horizon* programme *The Secret Life Of The Cat*, where two of the cats, Kato and Phoebe, living in houses opposite to each other across the street, were still disputing 'ownership' of the gardens between.

Cats are no more curious than other animals – in fact the saying should be 'stress killed the cat'



03

CATS ARE DOMESTICATED ANIMALS



CATS WITH PEDIGREES – Persians, Siamese, Russian Blues and Maine Coons, to name but a few – fit the biologist's criteria for a fully domesticated animal. Their owners control their breeding, feeding and care, just as with pedigree dogs, or for that matter, pigs and cattle.

However, most cats in Britain are 'moggies', not pedigree animals. Their mothers were probably pets, but when the mating season came around (usually January or February), they would have disappeared out through their cat-flaps and actively sought the attentions of as many males – tomcats – as they could find. It's possible that one or two of those toms might have been pets themselves, but nowadays most owners have their male cats

neutered to prevent them from roaming. This means that many of them would have been ferals, un-owned cats that live on their wits, and are extremely wary of people.

Each female, or 'queen', then observes the selection of tomcats she has attracted over a period of several hours, even as long as a couple of days, before selecting one or two which she allows to mate – something that would not be allowed by the owner of a fully domesticated animal. This behaviour has changed little during the course of domestication, confirming that moggies, at least, are still not fully domesticated animals.

Moreover, this courtship provides a mechanism whereby domestic cats can continue to evolve – the relative persistence of the tomcats and the preferences of the queens for particular



PHOTO: THINKSTOCK X3, GETTY X2, ALAMY

04

CATS KNOW WHAT THEIR OWNERS ARE THINKING



SCIENTISTS ARE DIVIDED as to whether any animal, other than us, has the ability to realise that the animals around them have minds at all. We use this 'theory of mind' so effortlessly that it can be hard to imagine not possessing it. For example, during a conversation we unconsciously choose our words carefully to get our message across, because we are able to imagine what the other person is likely to be thinking as we are speaking to them. We take into account that the person we are talking to has a mind somewhat like our own, but that there may well be subtle differences between our two minds because we are individuals.

Apart from perhaps our closest relations among the apes, other mammals seem to have only very limited 'theory of mind'. Dogs display a primitive version, known as 'attention-to-attention': they alter the way they signal to one another depending upon whether the other dog seems to be paying attention. However, this does not prove that they know that other dogs have minds. It could be the expression of a sophisticated set of rules for communication, such as 'if you can see both of the other dog's eyes, signal your intentions; if you can't, bark to get his attention'.

It's not clear whether or not cats reach even this level of sophistication: descended from a territorial species that had only limited opportunities for interaction with members of its own kind, it is unlikely that cats' brains would have evolved such an ability. So when your cat is looking at you, it will certainly be paying attention to you, but it's unlikely to be pondering whether you're thinking back, never mind reading your thoughts.



toms, both influence the characteristics of the next generation of kittens.

The very existence of feral cats further demonstrates that not all 'domestic' cats are fully domesticated. Domestic kittens are born to learn how to interact with people, but if they are deprived of human company for the first two months of their lives, they become wary of humans in general. They can adopt a feral lifestyle, scrounging or scavenging for their food.

On the other hand, if feral kittens are discovered before they reach the critical age of two months, and they are carefully introduced to people, they can quickly become indistinguishable from any pet cat.

Cats are therefore still capable of moving in and out of domestication within a couple of generations, something no fully domesticated animal can do. Your moggie probably has a wild side.



It's not hard to figure out what your cat is thinking: more cat food probably

05

A DOG'S SENSE OF SMELL IS MORE SENSITIVE THAN A CAT'S



GUN DOGS CAN pick up odours at concentrations 10,000 to 100,000 times lower than our relatively insensitive noses can. Cats, with their smaller noses, can only beat us by a factor of between 1,000 and 10,000. So in one respect, dogs *do* have a better sense of smell than cats.

But unlike humans, cats and dogs possess another olfactory sense – a second ‘nose’ that lies between the roof of their mouths and their nostrils. And cats beat dogs paws down in the resolving power of this second chemical sense.

The second ‘nose’, known as the vomeronasal or Jacobson’s organ, consists of a pair of fluid-filled tubes, each with one opening in the nostrils and the other just behind the incisor teeth. About halfway down, each tube connects with a pouch that contains a sense organ. To reach this organ, odours have

to first be dissolved in saliva and then pumped up into the pouch, producing sensations that must lie somewhere between smell and taste. The vomeronasal organ (VNO) even has its own area of the brain, the accessory olfactory bulb, where the information it produces can be processed separately from that generated by the nose proper.

Cats have a bigger range of receptors in their VNOs than dogs do (30 versus 9). Moreover, while dogs do not give any obvious indication that they are using their VNOs, cats do: they pull their top lip upwards, exposing their top teeth – and presumably also opening up the VNO ducts – in a grimace that looks rather fierce. This facial contortion, perhaps because we only discovered its significance quite recently, does not even have an English word to describe it. Biologists refer to it by its German name ‘Flehmen’.

Cats’ VNOs are probably more discriminating than dogs’ because they were originally solitary animals and so had to rely on scent marks to communicate with one another. When cats perform Flehmen, they have almost always just sniffed a scent-mark left by another cat, so they are presumably using their VNOs to get more detailed information about whoever left that mark. We caught many examples of this on the night-vision cameras deployed around Shamley Green, the Surrey village chosen for the BBC programme *The Secret Life Of The Cat*.

Research has yet to reveal the full extent of their vomeronasal organ’s abilities. But we do know that cats can identify other individuals from their scent marks if they’ve met them before and that even if they haven’t, they can tell the sex and reproductive state of the cat that left its mark.

A cat's nose may not be as sensitive as a dog's, but it can out-sense a canine with its vomeronasal organ



THINKSTOCK X2, TOPFOTO, SUPERSTOCK, ALAMY X2

PHOTO:



06

DOMESTIC CATS CAN BE TRACED BACK TO ANCIENT EGYPT, ABOUT 4,000 YEARS AGO



The Egyptian goddess Bastet depicted as a cat; domestic cats have their origins some 5,000 years earlier



IT'S STILL TRUE that this is where and when the earliest pet cats are placed by the archaeological evidence, but recent research into our pet cats' DNA has extended this story back another 5,000 years or so.

Dr Carlos Driscoll and his colleagues at the National Institutes of Health in Bethesda, Maryland, examined the mitochondrial DNA of hundreds of pet and wild cats. He concluded that the domestic cat and its wild counterpart, the Arabian wildcat *Felis silvestris lybica*, diverged not 4,000 but 10,000 years ago. Subsequently, domestic cats spread from their point of origin throughout the Middle East and North Africa. They occasionally interbred with wildcats, all the while becoming

progressively more distinct from them, especially in their ability to be tamed.

Precisely where that point of origin was is still uncertain: the DNA of today's wildcats from that place should be very similar to that of pet cats worldwide, but given the current political turmoil in the region, it has not yet proved possible to collect enough samples to pinpoint the location with any degree of certainty.

So, rather than a single and rather abrupt domestication event in Egypt, it seems that the domestic cat gradually evolved from the wildcat, over a period of several thousand years. Over time it became progressively more pet-like, while retaining the hunting ability that made it invaluable in keeping foodstores free from rats and mice.

07

MILK MAKES AN IDEAL FOOD FOR CATS



THE TRADITIONAL IMAGE of a contented cat lapping from a bowl of milk is a misleading one. Cats are very fond

of cream, which they value for its high fat content, and so they are especially attracted to milk that has come straight from the cow, especially after the cream has been allowed to rise to the top. However, the milk we now buy in supermarkets contains little fat, and while some cats may like it for its taste, many do not find it easy to digest.

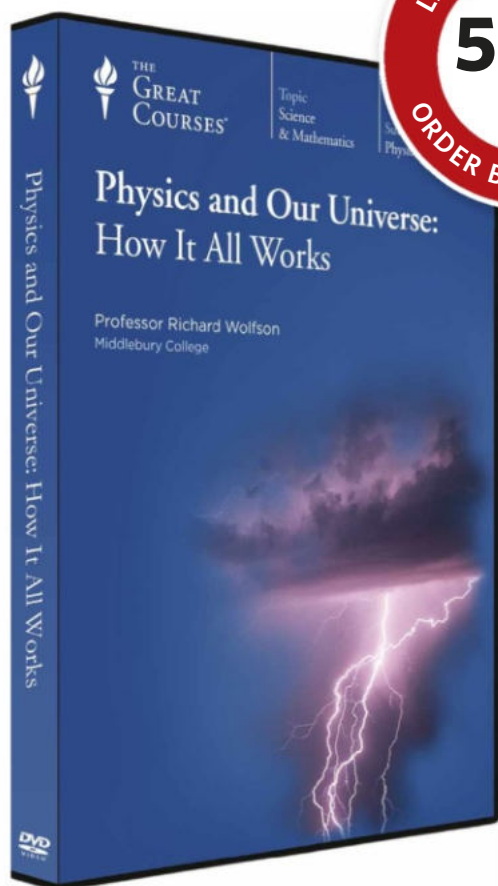
Like all infant mammals, kittens are born able to digest the main sugar in milk, lactose. This sugar is a very valuable source of energy for young animals, but soon after they are weaned, the enzyme that enables them to digest it, lactase, begins to disappear from the gut. When an adult cat drinks milk, the indigestible lactose in its gut may start to ferment, causing a stomach upset. ■

DR JOHN BRADSHAW is the author of *Cat Sense: The Feline Enigma Revealed*, (Allen Lane, £20)



Cats would prefer it if you gave them a sardine rather than indigestible milk





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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN



A caver explores a chamber of stalagmites and stalactites in New Britain, Papua New Guinea

NAOMI CHAMBERS, CHELMSFORD

How long does it take stalagmites and stalactites to form?

STALACTITES FORM WHEN water containing dissolved calcium bicarbonate from the limestone rock drips from the ceiling of a cave. As the water comes into contact with the air, some of the calcium bicarbonate precipitates back into limestone to form a tiny ring, which gradually elongates to form a stalactite.

Stalagmites grow upwards from the drips that fall to the floor. They spread outwards more, so they have a wider, flatter shape than stalactites, but they gain mass at roughly the same rate. Limestone stalactites form extremely slowly – usually less than 10cm every thousand years – and radiometric dating has shown that some are over 190,000 years old.

Stalactites can also form by a different chemical process when water drips through concrete, and this is much faster. Stalactites under concrete bridges can grow as fast as a centimetre per year. **LV**

PHOTO: BARCROFT MEDIA

In Numbers

\$1.5bn

is the budget for NASA's newest Mars rover, which will travel to the Red Planet in 2020 to search for traces of life

Q TRISTAN SMITH, WHITSTABLE

Which came first - time or space?



Time could be a product of space

A ACCORDING to Albert Einstein, space and time are simply different aspects of the same entity now called 'spacetime'. It therefore seems plausible that they came into existence simultaneously.

That said, recent research combining Einstein's work with quantum theory has led some theorists to conclude that space may actually give rise to the phenomenon we experience as time. **RM**

Q BEN GOODWIN, LEWES

How fast does a comet travel?

A COMETS ARE AT their fastest when closest to the Sun, a point in their orbit called 'perihelion'. The fastest comets are therefore ones that pass extremely close to the Sun. These 'sungrazers' can attain speeds of about 600km/s (1,350,000mph). But even at their furthest distance from the Sun (called 'aphelion') long-period comets can still be travelling at many thousands of miles per hour. **AG**

The 'sungrazer' Comet Kohoutek raced past the Sun in 1973



Q SIDNEY FELLOWES, LONDON

What is Bayes's Theorem and why are people talking about it?

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

The formula of Bayes's Theorem was used to predict the outcome of the US elections in all 50 states

A FEW MATHEMATICAL THEOREMS become the focus of best-sellers, health scares and headline-grabbing mysteries, but a 200-year old formula about probabilities has managed it. It takes its name from the Rev Thomas Bayes, an amateur mathematician who tried to solve a simple-sounding problem. If we suspect a coin is biased, we could toss it 100 times and see how many times it came up heads. Assuming it's fair, we know there should be around 50. But that assumption may be wrong – in which case, what should we conclude if we get, say, 34 heads? Bayes couldn't answer this question, but others did, using what's known as Bayes's Theorem, which shows how to update beliefs as new data accumulates.

This ability has made the theorem increasingly useful in a host of applications, from assessing medical screening results for cancer risk to finding the wreckage of an Air France airliner that vanished over the Atlantic in 2009. Bayes's Theorem is also the centerpiece of the best-selling book *The Signal And The Noise* by Nate Silver, who used it to correctly forecast the outcome of the 2012 US elections in all 50 states. **RM**

Q KATE MADDOCK, SALISBURY

Is a person being defensive when they cross their arms?

A PROBABLY, BUT NOT necessarily. Body language varies with age, sex and culture, but some features are more or less universal. Even blind people who have never watched anyone else doing it throw their arms in the air when victorious and cross their arms when defensive.

Crossed arms may have originated as a way of physically protecting your body. Men, when they are scared, can even be seen holding both hands over

their genitals as though they fear losing them, even when the threat is coming entirely from words.

Women are more likely to be seen 'self-hugging' – gripping their own upper arms. We all use and respond to these signals, whether consciously or not, and research shows that levels of hormones, including testosterone and cortisol, change with body position. But don't get too obsessed with the crossed-arms message.

Some people just cross their arms when they are bored or cold. **SB**



QUESTION OF THE MONTH

Kick the bucket on the Moon and you could end up looking like a piece of beef jerky



JACOB CRANTON, BOURNEMOUTH

Would a body decay on the Moon?

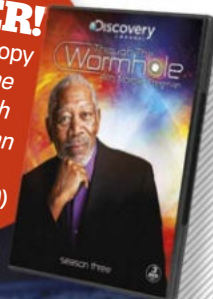
A NOT COMPLETELY. IF an astronaut died while he was still sealed in his spacesuit, the bacteria in the intestine would begin to multiply out of control and cause the body to swell with gas – mostly carbon dioxide, hydrogen sulphide and methane. But this wouldn't go on for very long. If the death occurred at night, the bacteria would only have as long as it took for the body to freeze solid because the temperature falls to -150°C . Our astronaut would stay like that until the next dawn, when they would thaw out as the Sun rose. And then begin to cook in the 120°C heat of the day.

Eventually the suit's airtight seals would give way and boiled water vapour would escape. The corpse would then freeze dry still further in the vacuum until it resembled a piece of beef jerky. Over the years, radiation and cosmic rays would cause the proteins to break apart into shorter amino acid chains, and fats would also break down.

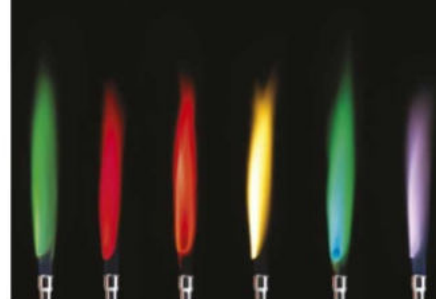
There would still be a recognisable humanoid husk even after a few millennia, and if the astronaut happened to die in one of the permanently shaded craters near the pole, his frozen corpse would be perfectly preserved almost forever. **LV**

WINNER!

Jacob wins a copy of *Through The Wormhole With Morgan Freeman Season Three* (Discovery, £8.99)



Left to right: the coloured flames of the elements copper, lithium, strontium, sodium, copper, and potassium



ALAN HUGHES-HALLETT, BY EMAIL

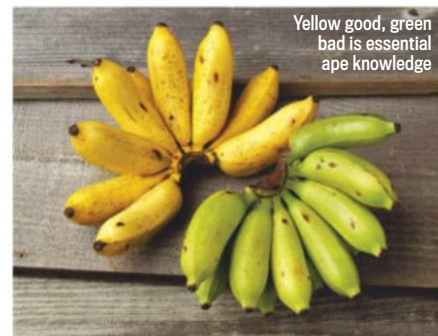
Why do flames have different colours?

A THE COLOURS WE see in flames depend on the elements that make them up. As atoms are heated in a flame they are thermally excited, which leads to the emission of photons. The different wavelengths of this light produce various colours, so copper will give off a green flame, whereas potassium will be lilac. **RM**

ALISON SHIELDS, BUCKINGHAMSHIRE

Why do bananas get sweeter as they ripen?

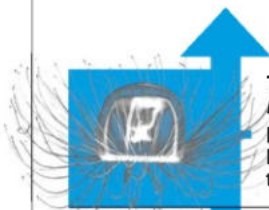
A FRUITS DISPERSE THEIR seeds when animals eat them. By suddenly increasing the sugar content, plants encourage animals to selectively eat the fruits with mature seeds that have developed the protective coatings they will need to survive passage through the digestive system. Commercial bananas don't actually have seeds, but the ripening process remains. **LV**



Yellow good, green bad is essential ape knowledge

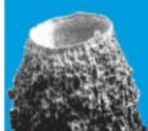
TOP TEN

LONGEST LIVING ANIMALS



1. *Turritopsis nutricula* jellyfish

Lifespan: immortal
Location: temperate to tropical regions of oceans



2. Giant barrel sponge

Lifespan: up to 2,300 years
Location: Caribbean waters



3. Ocean quahog

Lifespan: up to 507 years
Location: North Atlantic



4. Tortoise

Lifespan: up to 255 years
Location: worldwide



5. Tube worm

Lifespan: 250 years
Location: near hydrocarbon vents on the ocean floor



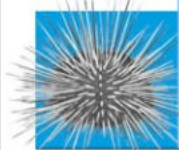
6. Koi (fish)

Lifespan: up to 226 years
Location: captivity



7. Bowhead whale

Lifespan: up to 211 years
Location: Arctic waters



8. Red sea urchin

Lifespan: over 200 years
Location: Pacific Ocean



9. Tuatara

Lifespan: up to 200 years
Location: New Zealand



10. Geoduck

Lifespan: up to 168 years
Location: off the west coast of North America



When will ducks evolve the ability not to quack when flying over farmland during the hunting season?

Q NATALIE JAMIESON, BASINGSTOKE

Why do ducks and geese 'quack' in flight?

A TO COMMUNICATE WITH other ducks and geese. The typical 'quack' we associate with ducks is only made by female mallards and a few other duck species. Males (drakes) make quieter, rasping sounds and do not quack. Geese are said to 'honk' rather than 'quack', but no human words can

really describe their sounds. Whatever names we give them, these calls are used mostly to keep the family together or call ducklings closer. This is true whether the birds are on land, on water or in flight.

When ducks and geese fly, their chest muscles contract on the downbeat of the wing stroke, and this is when they exhale and call. So the frequency of their calls depends on how fast they are flying. Quacking is quiet and slow when a duck is trying to keep her family together on the ground, but much faster and louder when flying. **SB**

Q TIM REYNOLDS, CANTERBURY

Can black holes fall asleep?

NGC 253, the Sculptor Galaxy, appears to have a supermassive black hole that's gone quiet

A SUPERMASSIVE BLACK HOLES reside deep in the cores of galaxies and create huge amounts of X-ray emissions as they continually devour material. Such objects are thought to hide in the heart of all galaxies. But recently, astronomers were surprised to find that one such black hole, in the Sculptor Galaxy (NGC 253), appears to have fallen asleep!

Observations by NASA's NuSTAR spacecraft have failed to detect X-ray

emission from NGC 253, whereas observations a decade ago by the Chandra X-ray Observatory showed telltale signs of the black hole feeding. Astronomers are not yet clear as to whether the black hole has become dormant or whether the Chandra observations were from a different source of X-rays. Researchers are now hoping the black hole will wake from its slumber, and they'll be ready to catch it if it does! **AG**

B BERTIE GREEN, LONDON

If a person is born blind and deaf, what language do they think in?

A NOT ALL THINKING requires language. We can think in pictures, 3D patterns, bodily gestures, movements, and almost anything else we have experienced. Deaf signers use language to think with, but experience it through imagined movements of their hands rather than as sounds. If a deaf and blind child is never taught language they have to rely on other ways of thinking. Most, however, are taught

Helen Keller (1880 – 1968) was a deaf and blind author and political activist



language through some kind of signing. In the most famous case, Helen Keller became deaf and blind at 19 months. Her teacher spelled words on her hands and she went on to become a writer and political campaigner. Presumably she thought using this language of touch. **SB**

WHAT IS THIS?



KNOW THE ANSWER?

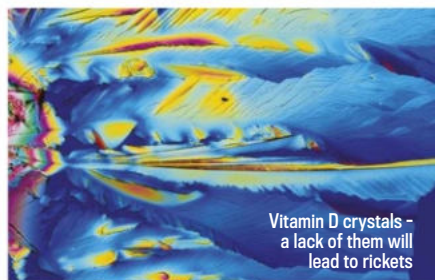
Go to sciencefocus.com/qanda/what and submit your answer now!

LAST MONTH'S ANSWER:

Well done to Richard Territt, who correctly guessed a Devil's Tooth fungus.

N NICK FOOT, NORWICH

How do we get vitamin D from sunlight?



A VITAMIN D ISN'T an ingredient of sunlight; sunlight triggers the reaction that makes it. Vitamin D is a group of related compounds and D3 is the one that requires sunlight. Cholesterol in our diet is first converted to 7-dehydrocholesterol and then UVB radiation in sunlight triggers a reaction that creates first previtamin D3, and then vitamin D3 proper. In the UK, you need the sunshine levels of a summer's day to create vitamin D and it only works outdoors, because glass blocks UVB radiation. **LV**

? Did you know?

Built by Herrenknecht AG, the Mixshield tunnel boring machine is the largest of its kind in the world at 15.43m in diameter.



S SUE WOOD, STOCKPORT

Why are drugs so expensive?

A THE JUSTIFICATION USED by drug companies is that researching, testing and obtaining the necessary approvals is a very expensive process – often £600 million per drug. The high price is to recoup these costs before the patent or exclusive marketing rights expire. But drug companies all have shareholders and have a duty to charge whatever the market will stand. The actual cost of



Getting drugs out of labs is an expensive business

manufacture is relatively low, so once patents expire, competition between drug manufacturers makes the price of drugs lower. **LV**

K KEITH STRINGER, LUTTERWORTH

Is it more hygienic to use a plastic chopping board or a wooden one?

A WOOD IS SLIGHTLY better. A new plastic chopping board is easy to clean, but a sharp knife creates shallow cuts in the surface that can trap bacteria. Putting it in the dishwasher is enough to clean it properly, but the lower temperatures of a hand wash won't kill the bacteria. Wooden



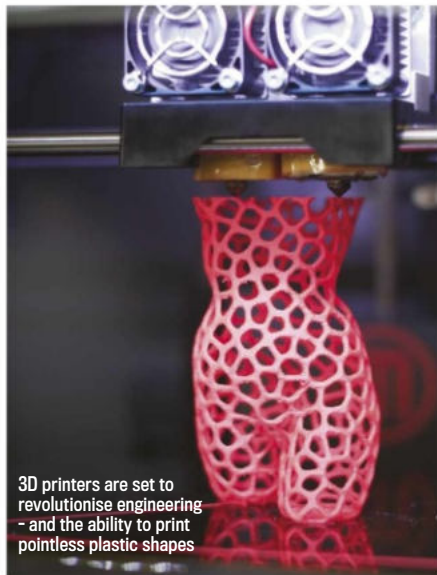
Bacteria can't multiply on a wooden board

chopping boards trap bacteria in cuts as well, but research at the University of California Davis showed that the bacteria do not multiply in the wood. **LV**

Q ED RAWLINGS, MANCHESTER

What's the difference between laser cutting and 3D printing?

A BOTH ARE TECHNIQUES for rapid manufacturing. A 3D printer is like an automated glue gun. A nozzle extrudes material, usually molten plastic, laying it down in layers. Gradually, the layers build up into a complete shape. In a laser cutter, a fine beam is focused onto a thin sheet of a material like acrylic. Under computer control, the laser head traces across the sheet, melting the material in a thin line and eventually cutting out a shape. Laser cutting is therefore a two-dimensional technology. However at the Hasso Plattner Institute in Germany, they have added a third dimension by using the laser to fold the material. By defocusing the beam, the acrylic melts sufficiently to bend but not enough to be cut right through. This so-called laser origami fabricates three-dimensional objects like pen holders quickly, without having to wait for a 3D printer to build them up in layers. **GM**



3D printers are set to revolutionise engineering - and the ability to print pointless plastic shapes

In Numbers

66,000,000

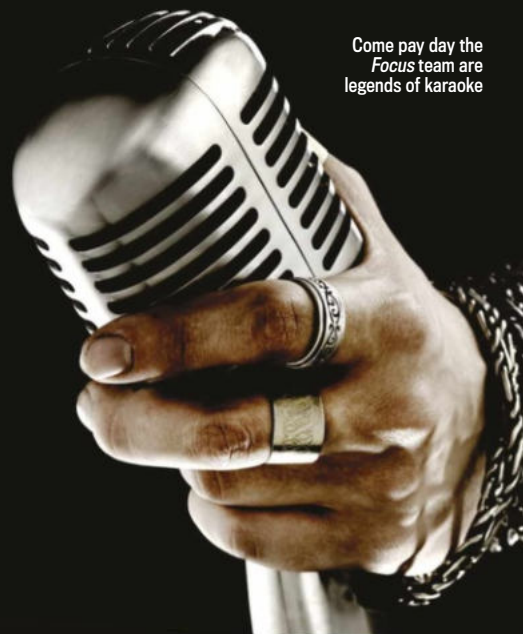
years is the age of a T-rex tooth found recently in South Dakota. It was broken and lodged in the spine of another dinosaur, a large, plant-eating hadrosaur.

Q LUIGI FILLETTI, MALTA

How does a microphone pick up sounds?

A A MICROPHONE CONVERTS sound into a small electrical current. Sound waves hit a diaphragm that vibrates, moving a magnet near a coil. In some designs, the coil moves within a magnet.

Other microphones, such as condenser microphones, work on the principle of capacitance. Capacitors consist of parallel conducting plates that store charge and are used to smooth out signals like voltage variations in a power supply. In a condenser microphone, the incoming sound vibrates one plate of a capacitor. The varying capacitance is converted into a corresponding electrical signal. **GM**



Come pay day the Focus team are legends of karaoke

Q MARY O'BRIEN, DONCASTER

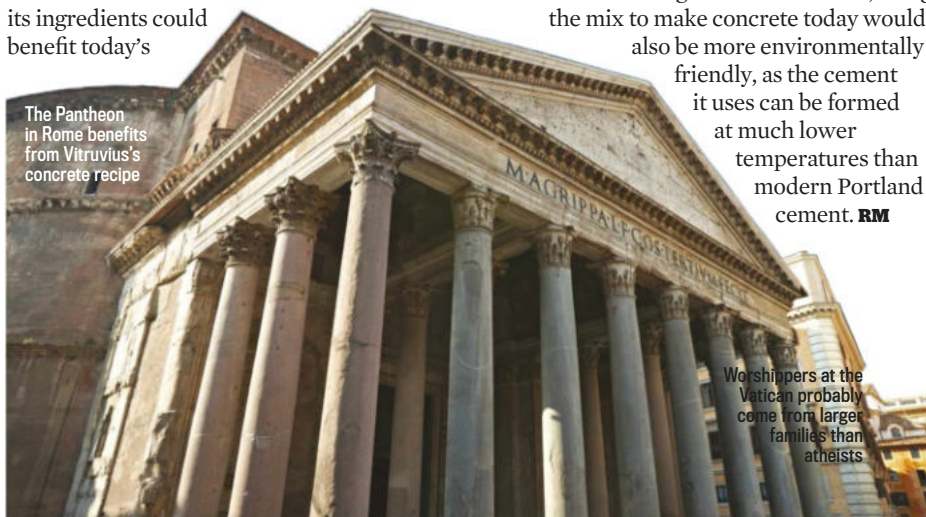
Why have many Roman buildings outlasted newer ones?

A IT'S NOT JUST that they've been given special protection over the centuries, even during wars. The Romans also used a form of incredibly tough concrete - so tough, in fact, that researchers think its ingredients could benefit today's

version. The original recipe was devised by Marcus Vitruvius Pollio, an engineer for the emperor Augustus, around 30BC. Chunks of rock were stuck together using a mortar made from lime and volcanic ash mixed with seawater. The result was used in structures ranging from breakwaters to the famous Pantheon in Rome.

A team at the University of Berkeley, California found that the mix - known as calcium aluminium silicate hydrate - is extraordinarily resilient, and can cope with centuries of immersion in highly corrosive seawater. According to the researchers, using

the mix to make concrete today would also be more environmentally friendly, as the cement it uses can be formed at much lower temperatures than modern Portland cement. **RM**



The Pantheon in Rome benefits from Vitruvius's concrete recipe

Worshippers at the Vatican probably come from larger families than atheists



HOW IT WORKS

FRACKING

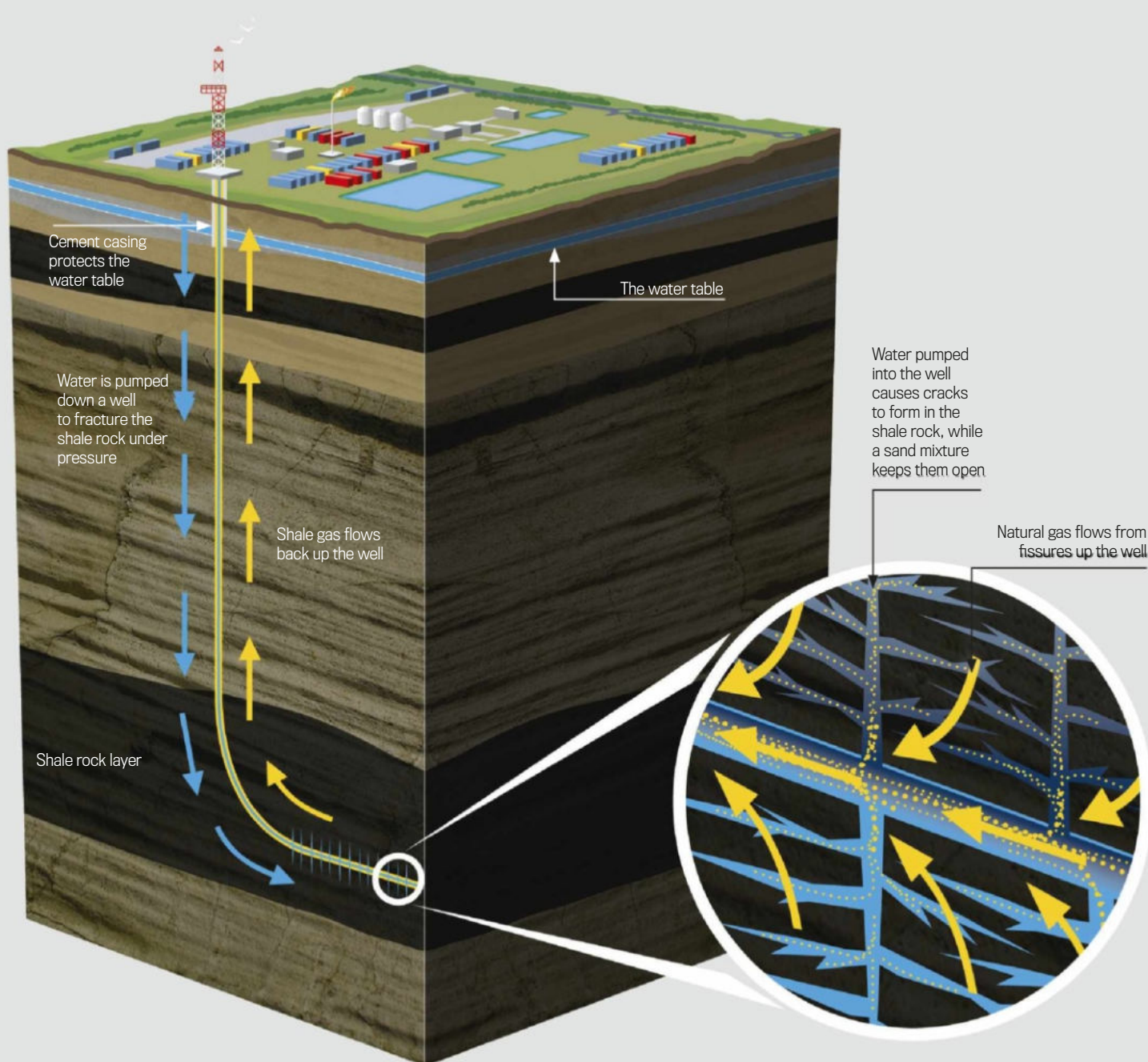
WHEN EARTH TREMORS were felt in Blackpool in 2011, the UK's only fracking site got the blame. Since then, the controversial technology has hardly left the news. Fracking, or hydraulic fracturing, is a method used to extract natural gas from rock found more than a kilometre

underground. It takes over a month to drill a well deep enough to reach the gas-filled layer, known as shale. As it descends, the drill bit transmits information about its location to the surface. Once deep enough, it can be steered round to pass through the shale horizontally.

Water, sand and various chemicals are pumped at high pressure down the well and force fissures to form in the solid shale rock. Water flows into these cracks and the sand in

the mixture holds them open. Once the water has been pumped back out, natural gas diffuses out of the cracks in the rock and up the well.

The UK is estimated to be sitting on enough shale gas to provide 25 years' worth of energy. Proponents of fracking argue it has the potential to lower energy prices and reduce coal consumption. But the risk of earthquakes, water pollution and methane leaks may keep its full potential locked deep underground.



THE NIGHT SKY: WHAT CAN I SEE IN SEPTEMBER?



Don't miss *The Sky At Night* on BBC One every month
www.bbc.co.uk/skyatnight

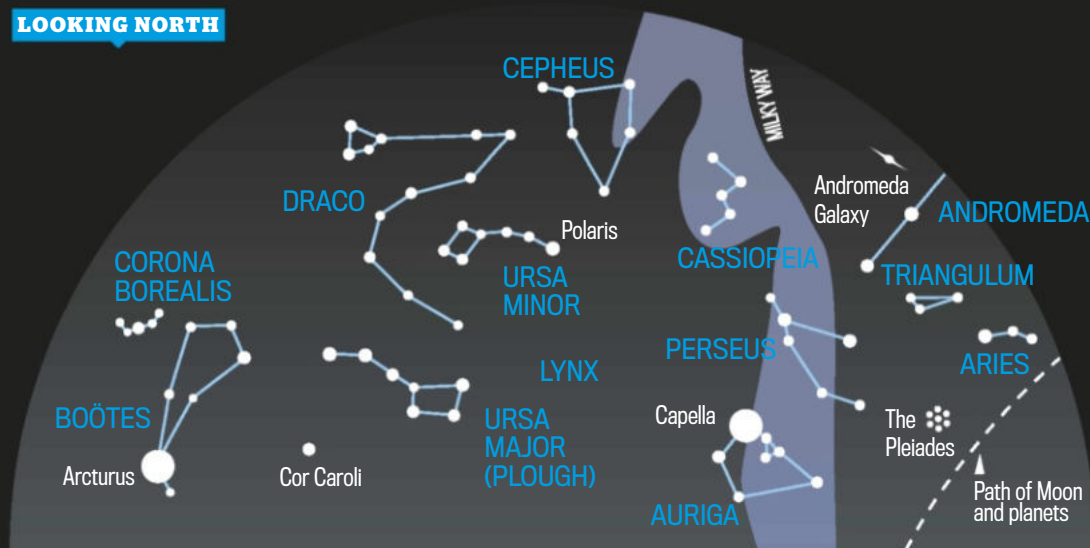
Astronomy with
 Heather Couper
 and Nigel Henbest



LOOK SOUTH TO enjoy a celestial aquarium! As well as a pair of fish (Pisces), we have a southern fish (Piscis Austrinus), a small dolphin (Delphinus), a whale (Cetus) and even a sea-goat with a mermaid-like tail (Capricornus). Keeping it all topped up is a man with a water jar (Aquarius). The ancient Babylonians – who drew these star-pictures – depicted this as a watery region of the sky, because the Sun passed through these constellations during their rainy season.

LOOKING NORTH

OVERHEAD



W

THE SKY AT 11PM (BST) IN MID-SEPTEMBER 2013

LOOKING NORTH

9 September, 4am

Mars is the brilliant red 'star' rising in the east around 3am; watch it carefully until dawn, and you may notice it looks a bit fuzzy. That's because the Red Planet is moving in front of the Beehive star cluster.

LOOKING SOUTH

All month, all night

Aquarius (water carrier) is a dim constellation. Ancient astronomers saw him pouring streams of water or – even better – nectar, the god's tippie. The liquid flows from a 'water jar' marked by a distinctive shape of four stars, like a steering wheel.

E

All month, late evening

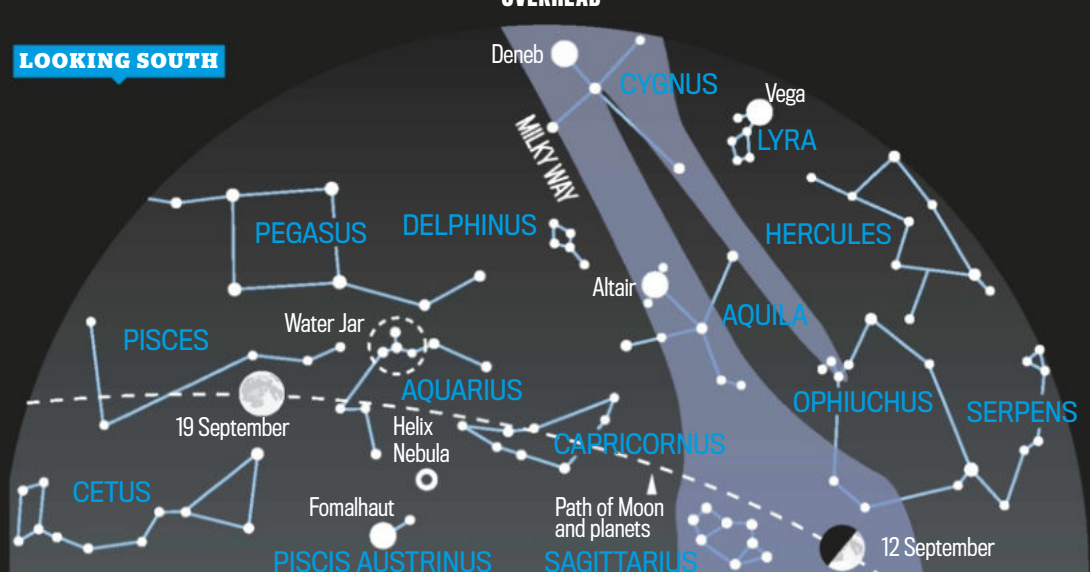
Just peeking above the horizon is the star Fomalhaut. It forms the mouth of the Southern Fish (Piscis Austrinus), swallowing water from Aquarius's jar. This young star is surrounded by debris from its birth – and astronomers have found signs of a planet forming in this dusty ring.

8 September, 8pm

To the southwest, spot the thinnest crescent Moon just below Venus, very low in the twilight glow.

LOOKING SOUTH

OVERHEAD



E

THE SKY AT 11PM (BST) IN MID-SEPTEMBER 2013

W

Find out more



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Q MATT PARKER, LEICESTER

Which has more health benefits, drinking hot water or cold?

A MOSTLY IT MAKES no difference. Any water that you drink will be absorbed by the intestines regardless of its starting temperature. If it wasn't absorbed, it would give you diarrhoea. Hot or cold drinks obviously have a temporary effect on your body temperature, but which one is better will depend on whether you need warming up or cooling down.

There is however some research to show that a hot

drink is better for you when you have a cold. Studies as far back as 1979 found that the steam from a hot drink increases the 'nasal mucus velocity'. As horrible as that sounds, runnier mucus is better because it stops the nose from blocking up altogether, which can lead to a secondary sinus infection. Chicken soup works even better, because the aroma of the soup increases the blood flow to your nostrils. **LV**



If you have a cold, put down the cool water and stick to hot drinks

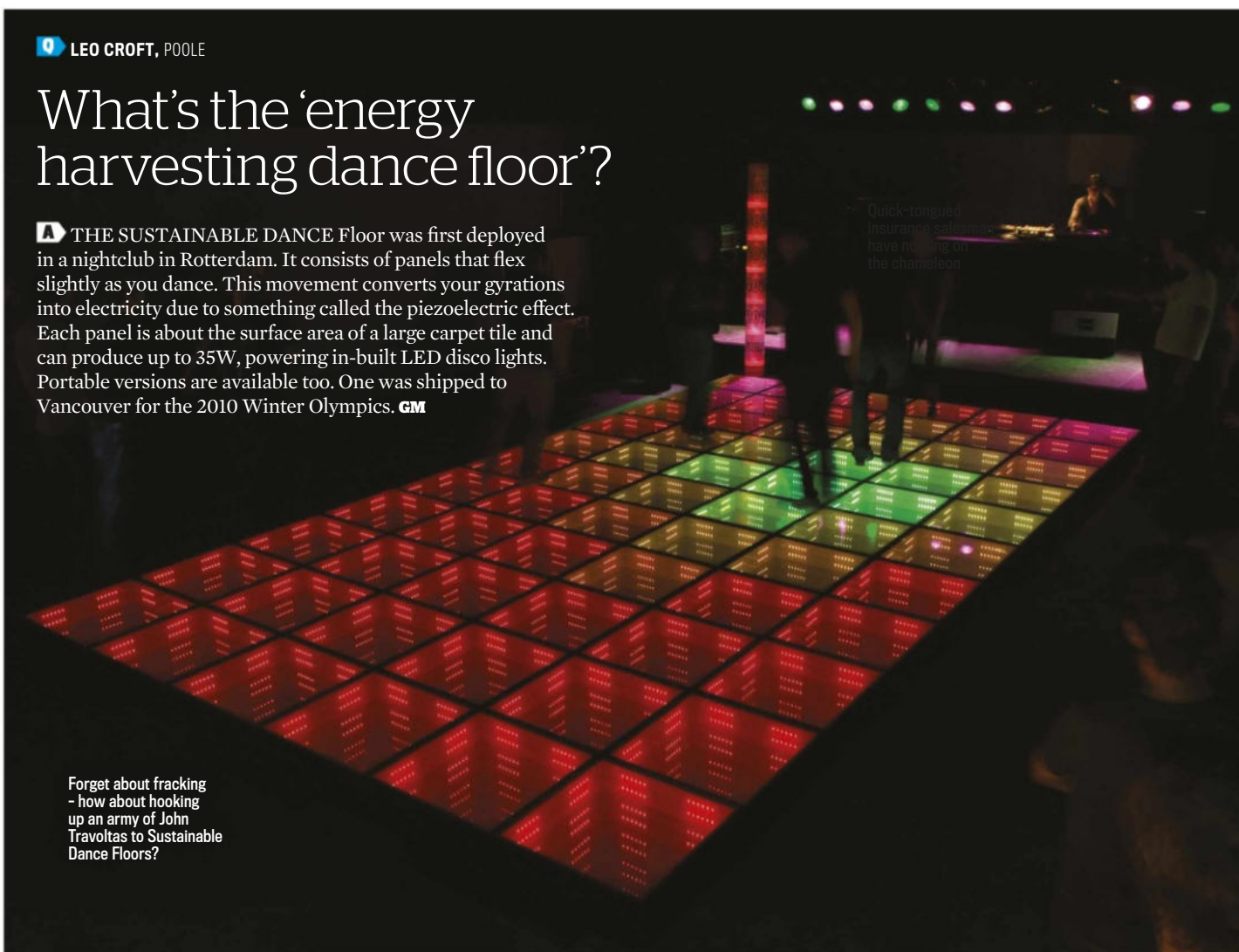
Q LEO CROFT, POOLE

What's the 'energy harvesting dance floor'?

A THE SUSTAINABLE DANCE Floor was first deployed in a nightclub in Rotterdam. It consists of panels that flex slightly as you dance. This movement converts your gyrations into electricity due to something called the piezoelectric effect. Each panel is about the surface area of a large carpet tile and can produce up to 35W, powering in-built LED disco lights. Portable versions are available too. One was shipped to Vancouver for the 2010 Winter Olympics. **GM**

Quick-tongued insurance salesmen have nothing on the chameleon

Forget about fracking - how about hooking up an army of John Travoltas to Sustainable Dance Floors?



Q JOSEPH VENABLES, WEST CHESHIRE

Why are blue eyes considered attractive?

A ONLY SOME PEOPLE think they are. In an experiment that manipulated eye colour, women thought brown-eyed and blue-eyed men were equally attractive. And brown-eyed men thought brown-eyed and blue-eyed women were equally attractive. It was only blue-eyed men who preferred blue-eyed women.

This may seem odd but there could be a simple evolutionary reason. Women can be certain that a child is their own but men cannot, and need to avoid bringing up another man's child. Blue

eye colour behaves like a recessive trait. This means that to have blue eyes you must have inherited two copies of the genes from your parents. So if a blue-eyed man has children with a blue-eyed woman and one of the children has brown eyes, he knows it cannot be his own. A preference for blue-eyed women could have evolved for this reason.

Another theory is that pupil size is more obvious in people with blue eyes, making it easier to read their emotions and whether or not they are attracted to you. **SB**



Finding blue eyes attractive could be an evolutionary trick to help you identify whether your offspring are actually yours

Q HARRIET MORRIS, ISLE OF MAN

Why doesn't milk curdle in tea?

A CURDLING OCCURS WHEN the proteins in the milk coagulate and separate out from the water and fat. Most of the protein in milk is casein, which is a molecule with a much less complicated structure than other proteins. Unlike egg proteins, heating casein isn't enough to curdle it; you need acid as well. So pouring milk into a hot cup of tea won't make it curdle.

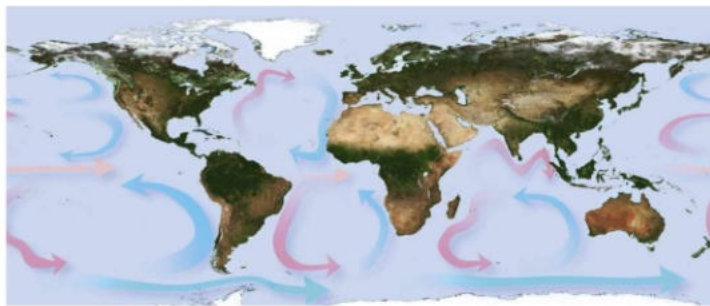
However, if the milk is slightly off the bacteria that then multiply in it produce lactic acid as a waste product. The slight acidity can be enough to make it curdle in hot tea. **LV**



You're almost at the end of this month's Q&A, so make yourself a cuppa

Q PAUL WAREHAM, MACCLESFIELD

Do ocean currents affect Earth's rotation?



The Coriolis effect makes currents move to the right in the Northern Hemisphere and to the left in the Southern Hemisphere

A IN FACT, IT'S the other way round; the Earth's rotation affects ocean currents. There are two main processes that give rise to ocean currents. First, wind drags on the water's surface, forcing it to move in the direction of the wind. This forms shallow currents that typically follow the prevailing winds. These winds generally move away from the equator where warm air rises and flows toward cooler latitudes.

Deep-ocean currents are driven by differences in the water's density, which is controlled by temperature and salinity (saltiness). But both these types of ocean current are affected by the Earth's rotation.

As ocean currents move away from the equator, the Coriolis force makes them deflect toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere. These major spirals of ocean currents are called 'gyres' and are a direct result of the Earth's rotation. **AG**

NEXT MONTH Over 20 more of your questions answered



For even more answers to the most puzzling questions, see the Q&A archive at www.sciencefocus.com/qanda

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THE FUTURE OF GADGETS

TECHHUB

➤ THIS MONTH

BILL THOMPSON
Augmenting senses
p81

JUST LANDED
TV that talks to your phone
p82

ULTIMATE TEST
High-end headphones
p85

EDITED BY **DANIEL BENNETT**

ON THE HORIZON

ADIDAS MICOACH SMART_BALL

THE NEW Premier League season has only just kicked off, but soon budding Van Persies will have a secret weapon: the Adidas miCoach smart ball. It may look like a regular football, but inside are sensors that record data on your kicks and send it to your phone. You can see where you're going wrong, and – crucially – compare your speed, bend, and other stats to compete for bragging rights with your mates.

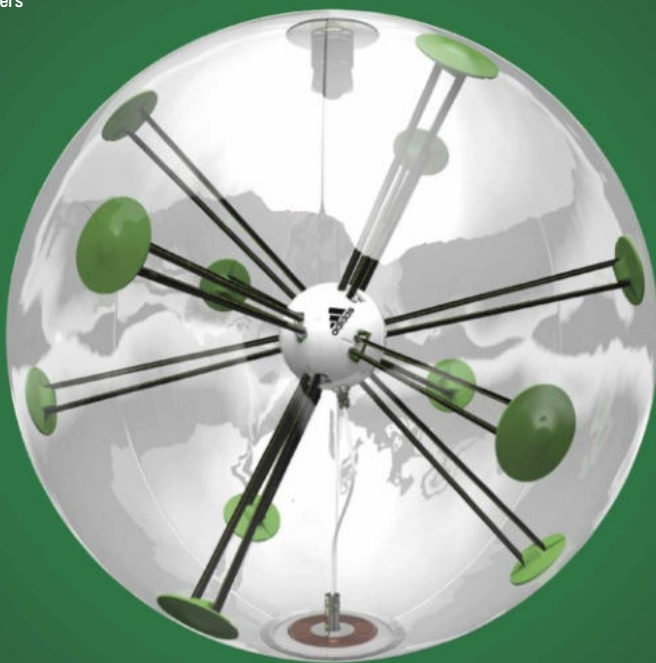
It's not the preserve of the pros, either. It'll be on sale sometime next year to any Tom, Dick and Harry who wants to improve their game. Or just show their mates who's got the hardest kick.

In use you wouldn't notice any difference between it and a normal ball: it's a standard 32-panel thermally bonded ball, and even meets FIFA guidelines. It'll respond exactly the same as the ball you'd use come match day: same flight, bounce, everything. ➡



ADIDAS.COM,
PRICE TBA

The miCoach smart ball has a sensor package held inside it by shock absorbers



But it's on the inside where the magic happens. That's where an accelerometer and magnetometer analyse the forces on the ball during flight. This sensor package is kept in the centre of the ball by a suspension system, which also protects it during impact.

These innards feed back info to an app on your phone (only on iOS, not Android) via Bluetooth 4.0. It'll tell you the launch speed, spin rate, spin axis, trajectory, where you made contact with the ball, and the bend. What info you get depends on which of the app's four modes you opt for. Kick It is the open mode if you just want to get started, while Get Better focuses on improving your skills, from ball handling to advanced bend. Challenge mode pits you against the pros, and Record Book saves your 10 best kicks of each day, highlighting improvements over time.

While it's aimed at consumers like us, this kind of technology could change how the pros play, too. "In a few years' time every ball in training could have a sensor built in to tell coaches how well the player is kicking it," says Dr Andy Harland, director of the Sports Technology Institute at Loughborough University.

Talent scouts could find it particularly handy, Harland says, as they'll have hard data to go on, instead of just trusting their gut instinct. This should please the clubs, seeing as they're the ones making the big investments. These stats could even be served up on TV coverage, so couch potatoes can see how hard our idols strike the ball, then head to the park and see how we stack up. Badly, in most cases.

It'll help bring football into the 21st Century too, Harland reckons. "Young people are used to having every aspect of their lives linked to their smart phones, so if football isn't, maybe it would become old hat," he says. "It's no secret football has been less prepared than some sports to embrace this kind of technology measurement system, but that's changing, with the likes of Hawk-Eye and Prozone. Technology is only going to become more important for football."

It sounds like this is just the start of a beautiful friendship for the beautiful game.

JOE SVETLIK is a freelance tech journalist and news reporter for CNET

TECHOMETER



WHAT'S HOT BT BROADBAND

The phone company has announced a blistering 300Mbps broadband service that will go on sale later this year. This equates to a hypothetical transfer rate of 37.5MB per second – you could download a movie in half a minute – and while actual speeds can vary this will make it the fastest broadband offered in the UK. When it launches it will cost £50 per month and include unlimited downloads.

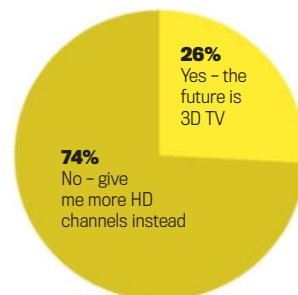
WHAT'S NOT 3D TV

The BBC is pulling the plug on its 3D-TV service. Kim Shillinglaw, the Beeb's head of 3D said that audiences found the experience "quite hassly". The announcement was made not long after the US sports channel ESPN announced it would be stopping its 3D programming. This could mark the beginning of the end for 3D TV.



READER POLL

Would you like more 3D TV channels?





EARLY ADOPTER

BILL THOMPSON

Give your senses a tech boost

HAVING NEVER owned an expensive car, I was surprised to get into a friend's new BMW and hear it start beeping as he reversed into a space. The beeps came from proximity sensors in the bumpers that provide a warning when you get close to other cars, bollards, or small children playing carelessly in the road.

The 'Park Distance Control' system in the BMW uses high-frequency sound, but you could use radio waves or any other signal that can be reflected off solid objects in order to measure the distance and provide feedback.

Such systems are not new. Radar, using radio waves for distance calculations, was developed during World War II while Lidar, using laser light for the same purpose, dates from the 1960s. However, some really exciting possibilities are emerging as different types of sensor become more widely available and more portable. This is especially the case when they are coupled with laptops and smartphones that can turn the distance information into data that machines can use to navigate their environment.

Researchers at MIT have developed a system for use by firefighters which packs a whole range

of sensors into a backpack, including a Kinect motion sensor. The various signals are processed in real-time and used to create a map of a building that can be used in search and rescue operations in dense smoke.

Meanwhile, a team at IDCAST – the Institute for the Development and Commercialisation of Advanced Sensor Technologies – has funded a project that is trying to



combine data from several mobile phones into a single virtual radar system. It will combine the limited data from each phone to make a 'virtual antenna' with a resolution usable for a range of imaging purposes. Each phone will act as a low-resolution radar system, measuring the reflection of the radio waves it transmits when making a call, and the resulting combined data could be used for medical imaging or even to 'see' through walls, if they are

made of the right sort of material. Companies could even use this data to map the inside of buildings, logging the positions of everyone inside.

As these new sensor networks develop, it could transform the ways we see and engage with the world, in effect supplementing our own senses. For example, complex analyses drawn from wearable devices – like Google Glass, for example – could let us look around walls, see imminent accidents or spot weather-changing patterns as we look at the sky.

These systems are often called 'augmented reality', but I think that's misleading. There has always been a gap between the real world and what our senses perceive. These new devices augment our senses and may help us build a better model that gets a little closer to reality, but they don't add anything to the world itself.

But whatever we call them, I think we're about to see a transformation in the way we experience the world as we get direct access to data from a range of sensors. It will take us far beyond the capabilities of our biological senses.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

COMING SOON

▶ 3 MONTHS

NOKIA LUMIA 1020

The line between compact camera and smartphone just got blurrier with this new Windows smartphone that sports a 41-megapixel camera. The high pixel count means you can 'zoom' into images digitally without loss of quality. nokia.com



▶ **Sony Xperia Z Ultra** Can't decide between a new smartphone or a new tablet? Why not get this mongrel? Sony's new 6.1-inch phone-cum-tablet is rumoured to be its next flagship device. Sony.com

▶ **Samsung Galaxy NX** When it goes on sale it will be the first interchangeable lens camera with 4G connectivity and an Android operating system. Samsung.com

▶ 6 MONTHS

IPHONE LITE

Snaps of brightly coloured – red, yellow, blue and green – iPhone shells have leaked from Apple's Chinese manufacturers. It's sparked rumours that a budget model of the world's most in-demand phone could be on the cards. Apple.com



▶ **Samsung ATIV Q** A tablet device that can switch between Android and Windows – very useful indeed if your work relies on Microsoft's ubiquitous Office software but you enjoy using Google's operating system. Samsung.com

▶ **LG smart watch** Wearable gadgets will be the next big boom in tech. Details are thin on the ground for LG's watch, but expect an Android-powered device that links via Bluetooth with your phone. LG.com

▶ 9 MONTHS

NEXUS Q

The *Wall Street Journal* reported that Google was having another bash at a media streaming device after its first attempt flopped spectacularly last year. An inside source also said Google was considering a system that would play games too. Google.co.uk/nexus



▶ **Mercedes S-Class** This car regularly sets the standard for the entire motoring industry and next year it will come with 'Distronic Plus Steering Assistance' or in other words autonomous driving on motorways. www5.mercedes-benz.com

▶ **Google Glass** The smart specs are being tested across the US and are due for a global launch next year. Google.com/glass



TELL US WHAT YOU THINK!

Would you like your senses enhanced by a resurgence in radar technology? Give us your opinion by emailing reply@sciencefocus.com



JUST LANDED

ONE-TOUCH TV

Your mobile phone and your TV are about to be best friends.
Jamie Carter tries the first set with near-field technology

THE MOST EXCITING 'smart' gadgets are regularly ruined by the need for passwords, login details and lengthy pairing procedures, so a new one-touch technology called NFC (near-field communication) was always going to find a place in the living room. Sony's new W8 and W9 Series of Bravia TVs use the contactless tech in an intriguingly simple manner; touch your smartphone to the TV remote control to initiate instant mirroring. Video, music, photos, apps and even web browsing can then be viewed fullscreen.

What is NFC?

It's a low-power data link between two devices, but it only works over a few centimetres. It's at its best where a brief 'tap 'n' go' link is required for identification; if your current credit or debit card hasn't got an NFC tag inside for contactless payment in shops, your next card may well have one.

However, as well as creating a digital wallet, NFC chips have been installed in almost all major Android smartphones and tablets (but not Apple products) in the last few years. So it's possible that you'll soon be waving your smartphone not just to pay for things, but to hold digital versions of tickets for trains,

SONY W9 BRAVIA ,
 SONY.COM, £1,799

planes and concerts – and also to link gadgets in your home.

Is NFC better than Bluetooth?

It's much quicker to set up, but data rates are far lower. NFC is an evolved form of radio-frequency identification (RFID) technology that merely identifies one gadget to another while using almost no energy, whereas Bluetooth uses up battery power and requires a long-winded pairing process between devices. Expect NFC to become the linking technology of the 'internet of things' whereby all electronic devices in the home and office communicate.

Can I play smartphone apps on the TV?

Apps are presented full-screen after the NFC link is made, but this is where the Sony TVs fall down slightly. Although displaying photos or playing music using Screen Mirroring was instantaneous (you can even pinch to zoom-in on photos in real-time), in our tests there was a lag of about half a second for video and games apps. Our hopes of ditching a games console to instead play wirelessly from a smartphone were dashed.

Should I buy one?

This is the first step into NFC technology for TVs, and as such

it's only used on expensive sets (the cheapest, the Sony KDL-42W805A, is £849). NFC should trickle down to cheaper TVs in 2014.

However, NFC is the future; your next Wi-Fi router will use NFC instead of a password, while Samsung and LG are using it to link smartphones to speaker docks, surround sound systems and Blu-ray players. Washing machines, vacuum cleaners and refrigerators are next...

JAMIE CARTER is a technology writer and the former editor of *Home Cinema Digest*





APPLIANCES OF SCIENCE

1 HELP FOR HILL CLIMBERS

If you like the idea of cycling to work, but are less keen on getting there in a hot mess, why not clip this little electric motor to the back wheel of your bike? The Rubbee can be clipped on to your frame in under a minute. Once attached, a small drive wheel sits on the rear tyre. This helps to propel you forward at speeds of up to 25km/h and with a range of 25km, it should be able to get you to work and back.

Rubbee
Price TBC, Rubbee.co.uk

2 HARD KNOCK LIFE

A blow to the head can be deceptive. The adrenaline rush of a rugby match can mask nasty knocks that could be harmful if left unchecked. To try to help players, from youngsters to professionals, Reebok has developed the Checklight cap. It contains a suite of sensors that monitor the severity of each collision, flashing red when it thinks you've taken a knock that is cause for concern.

Reebok Checklight
Price TBC, reebok.com

3 LOST AND FOUND

These stamp-sized tags, or Tiles, help you keep track of your valuables. Attach one to your keys, for example, and you can use an iPhone app to tell you exactly where it is, or to get the Tile itself to make a noise so you can find it. A Tile works within a range of 45m. Any further away and the app conveniently shows you the last GPS location that the Tile was within range.

Tile
\$24.95 (£16.26 plus P&P), thetileapp.com

4 TEACHING TOOL

Is there such a thing as a gadget with too much intelligence? Well now your pen can tell you off for making spelling mistakes. The Lernstift (it's German) learns your hand-writing style, translates it to text as you write and checks the spelling. Make a mistake and it chastises you by vibrating. It's intended to help children learn how to spell and write, so it tracks how many errors you make and your improvement over time.

Lernstift
£125, lernstift.com

5 A LITTLE BIRD TOLD ME...

The Canary is a stand-alone digital security guard – it only requires connecting to your Wi-Fi to work. Once set up, it uses a HD camera with night vision, microphones and motion detectors along with temperature sensors to keep an eye on your home. So if there's a temperature spike, which could be a fire, or it spots someone it doesn't recognise, it sends an alert to your phone.

Canary
\$199 (£130 plus P&P), Canary.is

6 A GLASS ACT

Google isn't the only one making smart glasses. Aimed at healthy types, the Recon Jet pairs with a smartphone via Bluetooth to give you all the heads-up information you might need. Whether it's map routes for your run, the weather forecast or just a live view of your heart rate, all the information is placed in your field of view. It sports an HD camera too so it can offer augmented reality and video recording.

Recon Jet
\$599 (£392 plus P&P), Jet.reconinstruments.com

DinoPC.com



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ULTIMATE TEST

SUPER SONICS

The latest phone-friendly headphones have more features than ever. **Joe Minihane** tests four of the best



THE DAYS OF shoving a pair of bog-standard earphones into your smartphone are nearing an end. The advent of improved wireless technology, with Bluetooth and NFC leading the charge, means cables will soon be a thing of the past. Professional quality sound technology, once the preserve of artists performing onstage, is being pared down and crammed into next-generation in-ear buds, while dedicated apps are giving us more control over the sound being pumped into our ears than ever before. And the four pairs of headphones on test here are at the forefront of this sound revolution. ➔

BEST BUY



SENNHEISER IE800

en-uk.sennheiser.com, £599

➔ LET'S NOT MINCE our words here: the Sennheiser IE800s are the best in-ear headphones we've ever used. The range is sensational, while the level of detail is ludicrously far from the cheap buds that mobile makers throw in with their smartphones. Whether you're streaming tracks on Spotify or listening to lossless audio, these headphones serve up the kind of sound only pros plugged into onstage monitors usually experience. Johnny Marr's riffs from *The Messenger* sound bright, lively and jangly, while the electronic bass throb of Disclosure's *Settle* swells while still picking up every last detail in the rest of the mix.

This is all down to Sennheiser's background in keeping musicians plugged into their sound while performing. The IE800s pack in the world's smallest extra-wide bandwidth transducer, which cuts down massively on distortion at louder volumes. This tech is usually found in larger cans and in-ear monitors for artists.

A specially designed chamber absorber ensures that there's much less frequency loss, so you can pick up on even the slightest details in a track. Yes, they're expensive (very!), but the IE800s point to a very near future when in-ears will be every bit as good as full-sized headphones.



PARROT ZIK

parrot.com/zik, £299.95

PARROT'S SUPERB ZIK cans not only use Bluetooth for serving up sound wirelessly, they also come laden with some whip-smart extras which are aimed squarely at the touchscreen generation.

Pairing them with a smartphone is made breezy thanks to the inclusion of NFC technology. As long as your phone has Bluetooth turned on, you only need touch them to an NFC-compatible device to get a prompt asking if you'd like to pair. We tried this on a Google Nexus 4 and found no difficulties. The only issue here is that the iPhone's lack of NFC means you have to go down the standard route of digging around in Settings to make things play nicely.

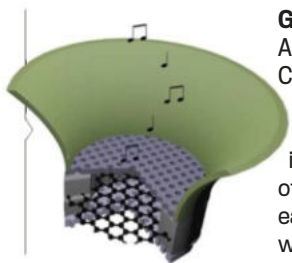
The Ziks produce a slick, well-rounded sound, although it can occasionally lack some of the depth that similarly priced wired cans produce. But the audio can be adjusted down to the last detail thanks to a very well thought out iOS and Android app, that lets you simulate the sound coming from different directions.

While the left earpiece's touch controls are nifty – you swipe across to skip a track, up and down to adjust volume and tap to pause – they can sometimes be a bit temperamental. The way the audio automatically pauses whenever you take the Ziks off is a clever touch, too.



FUTURE SOUNDS

Today's audio equipment is crammed full of features, but the next generation will start from scratch using new materials and designs altogether...



GRAPHENE

A team from the University of California, Berkeley has made earphones out of graphene. The miracle material's strength means it's stable across a wide range of audio frequencies, meaning the earphones can recreate sounds with spectacular accuracy.

FERROFLUIDS

Sony has recently rolled out speakers that use this futuristic technology. Rather than using dampeners to minimise vibrations, this design uses ferrofluids to take heat away from the speaker coils, with the result that there is far less distortion at high frequencies.





BEYERDYNAMIC CUSTOM ONE PRO

beyerdynamic.com, £155

SURE, THESE HEADPHONES can be customised by swapping out the panels on each earpiece for a different design. But what the name really refers to is the fact that you can tweak their bass output to your heart's content, thanks to sliding buttons at the bottom of each can.

Sticking on Savages' bass-driven alt-rock LP *Silence Yourself*, we were greeted by a reassuring thud with plenty of midrange detail. Using the sliders, we were able to open up the headphones' drivers by different degrees, with four different settings available. Open them right up and the bass goes full throttle. We felt as if we were

standing next to the speakers at the front of a particularly sweaty east London venue. Close them, though, and the sound on guitar-led tracks at least can feel a tad washed out.

Where the Beyerdynamics really come into their own, though, is with dance music and hip hop. We tried out *Settle* by Disclosure with the drivers fully open and found that the sound was about as close as you'd get to actually being in a club.

However, the cans' rather tight-fit and uncomfortable ear pads mean that you probably won't want to wear them for extended periods.



LOGITECH G430

logitech.com, £69.99

AIMED AT GAMERS rather than music lovers, Logitech's headset packs in full Dolby 7.1 Surround Sound. Stick on a first-person shooter and you'll be wowed by the sound you can pick up, from gunshots whistling past your head to footsteps creeping up behind you. The level of immersion is certainly impressive, especially with noise-cancelling tech thrown in: you're likely to lose yourself in the game and forget that you're actually on a sofa in your front room. The G430s are also designed with multiplayer in mind, so you can get crystal clear instructions from fellow gamers as you plan your way through particularly tough terrain. The

in-built mic means you can chat away happily, too.

On the downside, the garish blue of the headband and ear pads is hard to ignore, and we found they became a bit uncomfortable after extended use. But at under £70 they're great value, given the tech inside. Flip the mic up and they can also serve as more than passable music headphones, with great treble and midrange sound. The surround sound will still work with music, albeit not as impressively as it does with games.



JOE MINIHANE is a technology and travel journalist



KEVLAR

The material from bulletproof vests has been a staple in top-end speakers for years, and it's set to migrate to headphones. Like graphene, when used in speaker cones it allows great sound without using fragile paper or plastic.



SELF-ADJUSTING EARBUDS

A recent Apple patent application revealed plans to boost sound when an in-ear headphone doesn't 'seal' properly within the wearer's ear, ruining noise cancellation. These buds can detect a bad fit and adjust audio settings accordingly.

BONE CONDUCTION

Aimed at sporty types, bone conduction headphones have been around a few years but are becoming more common. They sit around your ears, and send sound as vibrations through your skull.



WHAT POWERS THE SUN

BY ALEXANDER HELLEMANS

Until the 19th Century, no one had any idea how the Sun produced energy. Understanding the atomic nucleus and the chameleon-like nature of an elusive particle finally resolved the mystery

F

OR THE ANCIENT Egyptians, the Sun was the eye of Ra, the Sun God, the source of heat, light, and life-giving power. In fact, the Egyptians were quite close to the truth; we now know that the Sun's energy has allowed life to develop on Earth.

The scientific revolution of the 17th Century placed the Sun at the centre of the then-known Universe. The nature of the Sun, and why it was glowing hot, remained unquestioned until the middle of the 19th Century, when scientists started wondering how heat related to the power of steam engines.

By then, Newtonian mechanics, initiated by Newton and Galileo, had developed to a high degree. The theory allowed the precise calculations of planetary orbits around the Sun, and the determination of the Sun's mass. The French engineers Nicolas Léonard Sadi Carnot and Émile Clapeyron studied what could make steam engines more efficient, and they were the first to create a new branch of physics: thermodynamics.

In the 1840s, the British scientist James Prescott Joule performed his famous experiments converting mechanical work directly into heat and was able to determine the relationship between these two forms of energy. This experiment supported Hermann von Helmholtz's idea that mechanical motion, heat, and radiation are different manifestations of what he called 'force', which now corresponds to the modern concept of energy. With it came the realisation that any source of power, such as the combustion of coal, is finite, and scientists started to wonder what was the seemingly infinite source that powered the Sun.

SOLAR POWER

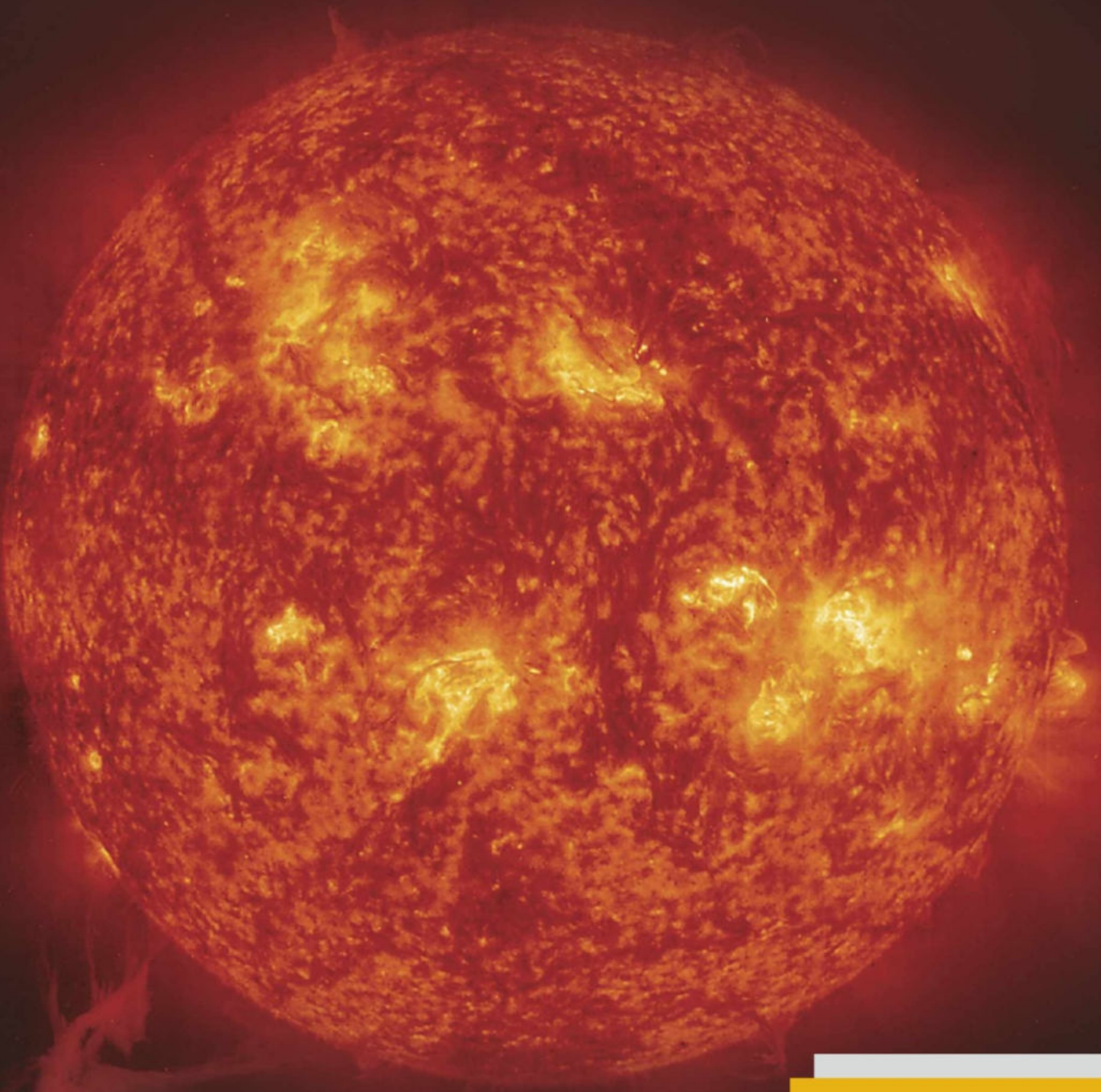
The Scottish physicist John Waterston, interested in determining the age of the Sun, found that if the Sun was powered by combustion, it would have burned out in 20,000 years. At that time geologists already had enough evidence that the Earth was several millions years old. So in

1853 Waterston proposed that the Sun could be heated by the continuous impact of meteorites, an idea that already had been advanced by the German scientist Julius von Mayer in 1848. But meteorites would heat the Sun for only one million years.

Helmholtz fell back on the views of the German philosopher Immanuel Kant and the French mathematician and astronomer Pierre-Simon Laplace that the Sun was formed by the contraction of a huge gas cloud – a theory viewed as correct today. He argued in 1854 that the compression of the gas cloud caused the Sun to heat up, an idea defended by the British Physicist William Thomson (Lord Kelvin) until the 1890s.

Kelvin figured out that the Sun could not be more than 40 million years old, and he clashed with the geologists and biologists of the time. For example, Charles Darwin's views on evolution required the Earth to be much older. By the end of the 19th Century, geologists had sufficient evidence that the Earth had to be more than a billion years old, and





The Sun provides Earth with abundant energy, produced by a nuclear reaction that took physicists decades to figure out

> IN A NUTSHELL

Find out how scientists made the intellectual journey from believing that the Sun was powered by an endless meteor bombardment, to discovering a nuclear reaction that stretched our understanding of physics to its limits.

not 20 to 40 million years, which is how long it would take the contraction of a gas cloud to heat the Sun. It was clear that a solution to the controversy between astronomers and geologists had to be found outside the known physics at the time.

The first glimpse of a possible solution came from an unexpected source. The American geologist Thomas Chrowder Chamberlin suggested in 1899 that “unrecognised sources of heat” may exist inside the Sun, energies of an “atomic or ultra-atomic nature”. Kelvin rejected this idea, but the discovery in 1903 of a weird property of the chemical

element radium, recently isolated by the French physicists Marie and Pierre Curie, made Chamberlin’s idea acceptable.

The material had a mysterious heat source that kept it hot. The British physicists Ernest Rutherford and Frederick Soddy soon identified it as radioactivity: atoms decaying by splitting up into smaller atoms. The mass of the newly formed atoms is less than that of the original atoms splitting up, and this tiny difference in mass is transformed into energy according to Einstein’s formula for the equivalency of mass and energy: $E=mc^2$. Therefore, it was not surprising that Rutherford

thought that nuclear fission, the same reaction mechanism that produces heat inside the Earth and in nuclear reactors, could also heat up the Sun.

In the meantime, by analysing the solar spectrum, astronomers had identified the chemical composition of the solar atmosphere, the outer gas layer of the Sun. The Sun appeared as a huge ball of hydrogen with small amounts of heavier elements, such as helium, oxygen and carbon. It became clear that there was insufficient uranium or other heavy elements present in the Sun that could produce the Sun’s energy output by nuclear fission reactions.

THE KEY EXPERIMENT

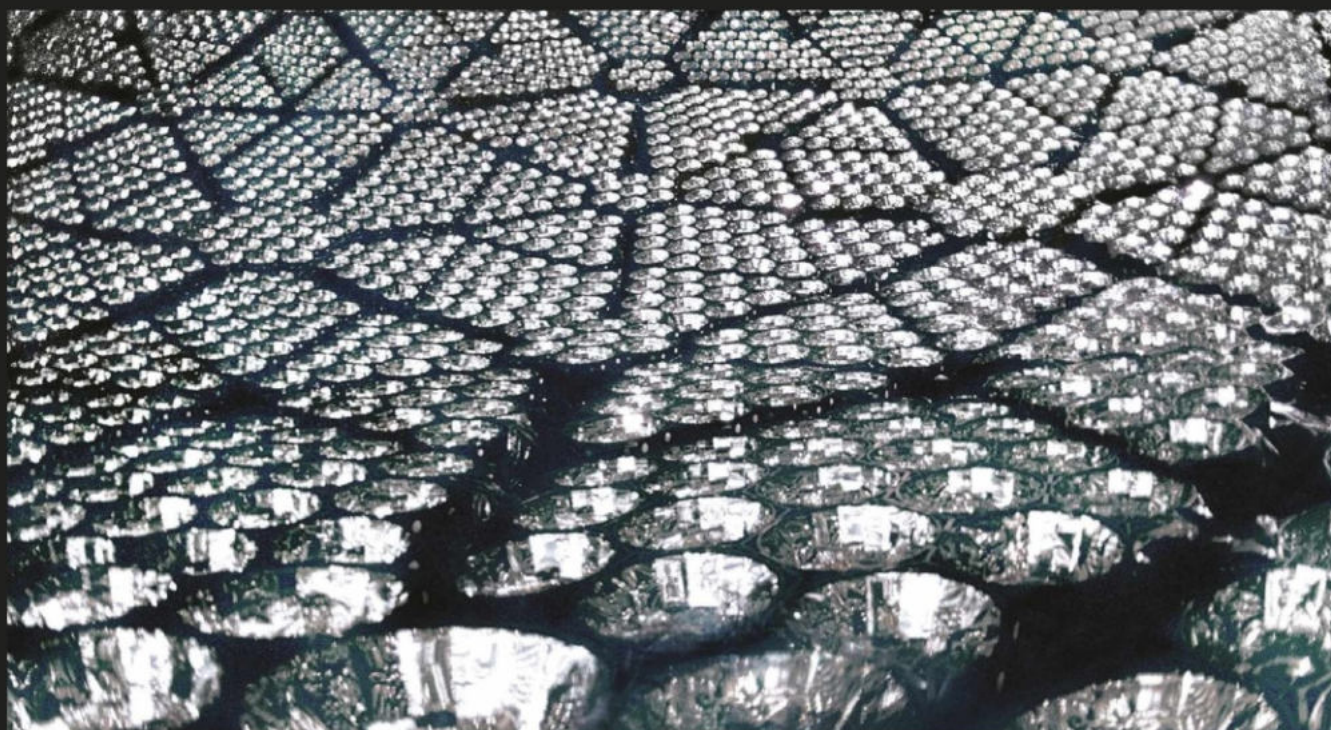
Major new scientific breakthroughs often require huge experiments. The Sudbury Neutrino Observatory is a large piece of equipment to detect something incredibly small

THE EQUIPMENT THAT detected neutrinos from the Sun was the Sudbury Neutrino Observatory (SNO) in Ontario, Canada. It consisted of a ball-shaped container filled with 1,000 tonnes of heavy water, in which hydrogen atoms are replaced by atoms of deuterium – a type of hydrogen having a proton and a neutron in its nucleus. The container was surrounded by a sphere consisting of 9,500 photomultiplier tubes.

The neutrinos interacted with the deuterium nuclei, producing electrons. In one interaction, a neutrino hits a deuteron (a proton and a neutron forming the nucleus of a deuterium atom), and ejects an electron. In a second type of interaction, a neutrino kicks an electron out of an atom. These electrons travel in the liquid at speeds faster than the light does. In doing so they give off what’s called Cherenkov radiation, a cone of light

that’s comparable to the sonic boom heard when an airplane breaks the sound barrier.

The photomultiplier tubes detected the light cones and their orientation. The fact that light radiated in the opposite direction from the Sun was proof that the neutrinos came from the Sun. The SNO not only distinguished between the three flavours of neutrino but also confirmed the results obtained by Raymond Davis.



Photomultiplier tubes at the Sudbury Neutrino Observatory surround a vast chamber filled with water to detect a fleeting glimpse of a neutrino

If atomic nuclei can split into smaller nuclei, why would smaller nuclei not be able to 'fuse' into bigger ones? This was what the American chemist William Draper Harkins was asking himself. He was studying ways in which larger atomic nuclei, such as helium nuclei, could be formed from hydrogen nuclei.

He proposed in 1915 that the fusion of hydrogen atoms, forming helium atoms, would also produce heat according to Einstein's energy formula. At that time, the nuclei of atoms were believed to consist of protons only. Since helium nuclei are four times more massive than hydrogen, he argued that four hydrogen nuclei would fuse into one helium nucleus, and the mass of the helium atoms formed would be slightly less (0.77 percent) than the sum of the masses of the hydrogen atoms.

NEUTRON BOMB

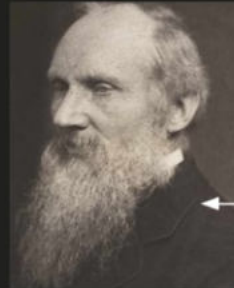
However, it was difficult to explain the stability of atomic nuclei heavier than hydrogen by assuming that they're made up only of protons. They would repel each other, due to their electric charge. In 1920, Harkins, and independently Rutherford, predicted the existence of an unknown, electrically neutral particle that had to be holding the protons inside the nucleus together. It was the neutron.

James Chadwick discovered this particle in 1932. The existence of the neutron resolved the problem of the disparity between an atom's atomic number (the number of protons in the nucleus) and the atomic mass (the number of protons and neutrons). This discovery made it possible to develop a theory for fusion reactions, and in 1939 the German physicist Hans Bethe (and independently Carl von Weizsäcker) developed nuclear fusion mechanisms that convert hydrogen into helium in the Sun and stars.

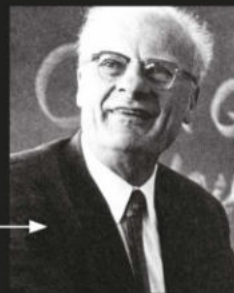
For low-mass stars, such as the Sun, Bethe developed the proton-proton mechanism. Protons (hydrogen nuclei) in the Sun's core would collide with each other, due to the extremely high temperature. An additional quantum effect, called 'tunnelling', would help to overcome the electrostatic repulsion between the protons. The helium nuclei formed, consisting of two protons, would not survive. But Bethe found that if one of the protons changes into a neutron – a reaction

CAST OF CHARACTERS

The big-hitters of physics who managed to unravel the mysterious force powering the Sun



William Thomson (Lord Kelvin) (1824–1907) was a British physicist and one of the founders of thermodynamics. He argued that the Sun was heated by the contraction of a gas cloud, and was not more than 40 million years old, which was counter to mounting geological and evolutionary evidence that the Earth was much older.



Hans Bethe (1906–2005) – a German and American nuclear physicist, he received the Nobel Prize for Physics in 1967 for his research into the nuclear reaction mechanisms in the Sun and stars. It resulted in the accurate description of two different fusion reactions by which stars convert hydrogen to helium.



Bruno Pontecorvo (1913–1993) proposed the use of chlorine atoms that would transmute into radioactive argon atoms for the detection of neutrinos. The Italian physicist also predicted that the three types of neutrino would continuously change from one type into another.



Raymond Davies (1914–2006) set up the Homestake Experiment to detect the neutrinos emitted by the Sun in collaboration with John Bahcall. The American physical chemist detected fewer neutrinos than predicted by John Bahcall, detecting only electron neutrinos.



John Bahcall (1934–2005) was an American theoretical physicist who predicted the production rate of neutrinos in the Sun. The predicted neutrino flux was larger than that measured by Davis's Homestake Experiment but was confirmed in 2001 by results from the Sudbury Neutrino Observatory.

TIMELINE

It took the best part of a century to pin down the exact mechanics behind the Sun's endless source of energy

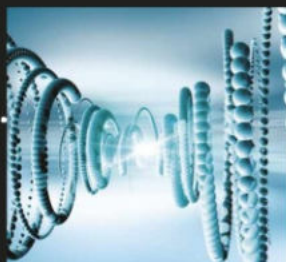


Wolfgang Pauli postulates the existence of an as-yet unknown neutral and massless particle, **the neutrino**. It would be emitted in certain nuclear reactions.

1930

1939

Hans Bethe and Carl von Weizsäcker (pictured) work out the **two nuclear fusion mechanisms** occurring in stars: the proton-proton reaction for smaller stars like the Sun and the CNO reaction cycle for larger stars.



Bruno Pontecorvo advances the idea that neutrinos change from one 'flavour' into another, a phenomenon known as **neutrino oscillation**. In 2001, data from the Sudbury Neutrino Observatory proved he was right.

1957

1968

Raymond Davis publishes his first results with his underground solar neutrino detector in the Homestake Mine in South Dakota. He detects only a third of the number of neutrinos predicted by John Bahcall in 1964.



Data from the **Sudbury Neutrino Observatory** (pictured) confirms the existence of neutrino oscillations, showing that neutrinos have mass, and also confirms the results obtained by Raymond Davis and the computation of the neutrino flux by John Bahcall.

2001

➔ called beta decay – the nuclei, consisting of two protons and two neutrons, would not fly apart. The resulting helium nuclei would be lighter than the hydrogen nuclei that formed it, with the difference in mass being converted into heat.

However, this was only a theory, and at first it looked like it wouldn't ever be possible to find out if the proposed proton-proton reaction mechanism was correct. But then the nuclear physicists got lucky. A new kid arrived on the block: the neutrino.

Physicists had found that a mysterious particle was carrying energy away in certain types of radioactivity, called beta decay. In the reaction, a neutron in an atomic nucleus converts into a proton and emits a beta particle (an electron). The energy of this beta particle was not constant – something had to be carrying energy from it.

The Austrian physicist Wolfgang Pauli, one of the pioneers of quantum theory, suggested in 1930 that yet another unknown particle, this time with no mass, was emitted along with the beta particle. The Italian nuclear physicist Enrico Fermi christened this particle the neutrino – 'small neutron' in Italian. But unlike the neutron, neutrinos hardly interact with matter. Their existence was only confirmed experimentally in 1955. In the following years, scientists found that nuclear reactions emitting electrons, tau particles and muons also produced different types or 'flavours' of neutrinos, respectively called electron, tau and muon neutrinos.

LOOKING INSIDE THE SUN

One type of beta decay, converting protons into the neutrons required to form helium nuclei, was thought to take place in a chain reaction inside the Sun. Neutrinos should therefore be formed abundantly. Raymond Davis, an American physical chemist, proposed in 1955 that because these neutrinos are hardly stopped by the Sun's outer layers, capturing them should allow us to 'see' inside the Sun. The American physicist John Bahcall had computed that 65 billion neutrinos emitted by the Sun pass through your fingernail every second but detecting them was another matter entirely.

Davis decided to use a neutrino capture idea proposed in 1946 by the Italian-British physicist Bruno

NEED TO KNOW

Key terms that will help you understand solar fusion

1 BETA DECAY

A nuclear reaction in which a proton is transformed into a neutron, with the emission of a positron and a neutrino, or when a neutron is transformed into a proton, with the emission of an electron and an anti-neutrino.

2 NEUTRINO FLAVOUR

Neutrinos exist in three flavours (or types) – electron, muon or tau neutrinos. This depends on whether they are produced in conjunction with a nuclear reaction producing an electron, a muon, or a tau particle. Neutrinos continuously change flavour in a process called oscillation.

3 NUCLEAR FUSION

A nuclear reaction in which smaller nuclei combine to form larger nuclei, such as the combination of hydrogen nuclei to form helium nuclei.

4 STANDARD MODEL

The general mathematical framework that describes all the elementary particles and their interactions. The Standard Model has been successful in the prediction of new particles, such as the Higgs, W and Z bosons, but was wrong in stating that neutrinos had no mass.

Pontecorvo: neutrinos hitting chlorine atoms would transform them into radioactive argon atoms. In 1967, Davis completed a huge neutrino detector, built 1,500m underground to protect it from cosmic radiation, in the disused Homestake Gold Mine in South Dakota. It consisted of a tank containing almost 400,000 litres of cleaning fluid, which contains the chlorine atoms that have to capture the neutrinos. The first results, published in 1968, were puzzling: Davis detected three times fewer radioactive argon atoms than predicted by Bahcall.

For more than two decades, Davis doggedly kept retuning and refining his neutrino detector, but to no avail, the results fell short by a factor of three. The problem became known



Located 1,500m underground this tank was filled with 100,000 gallons of perchloroethylene at the Homestake Gold Mine, Dakota, to detect fleeting neutrinos

as the 'solar neutrino deficit' and it became clear that either his detector was faulty or Bahcall's computations were wrong.

In 1967, before Davis published his results with his neutrino detector, Bruno Pontecorvo predicted that solar neutrinos could change type (flavour). The Homestake experiment could only detect electron neutrinos, and Pontecorvo argued that a good number of the electron neutrinos – the neutrinos produced in the Sun's core – would change into tau or muon neutrinos while travelling towards Earth. As these neutrinos don't interact with chlorine atoms in Davis's detector, it would reduce the number of neutrinos detected.

In the following years, what became known as the 'Solar neutrino deficit' was also discovered in other underground neutrino detectors. Scientists started seriously questioning Bahcall's computations. He finally got off the hook in 2001, when data from

the Sudbury Neutrino Observatory (SNO) (see 'The Key Experiment') 2km underground in a nickel mine in Ontario, Canada, became available. The SNO used a huge tank with heavy water in which all three types of neutrinos could be detected. Not only did it confirm Bahcall's neutrino flux computations, it also proved that neutrinos have mass.

Just 71 years since it was proposed, the understanding of neutrinos confirmed how the Sun supplies us with energy. ■

Alexander Hellemans is the co-author of *The History Of Science And Technology*

Find out more

 Listen to *In Our Time*, in which Melvyn Bragg discusses the detection of neutrinos from the Sun.
www.bbc.co.uk/programmes/b0106tjc


Feed your mind



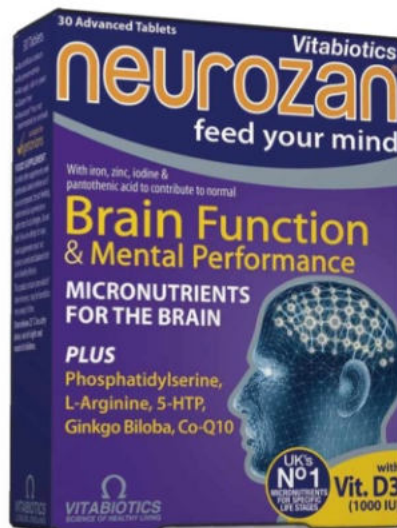
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Neurozan® is an advanced, comprehensive formula to help safeguard your daily intake of essential vitamins and minerals. Including iron, zinc and iodine which help to maintain normal **brain function** and pantothenic acid which supports normal **mental performance**.

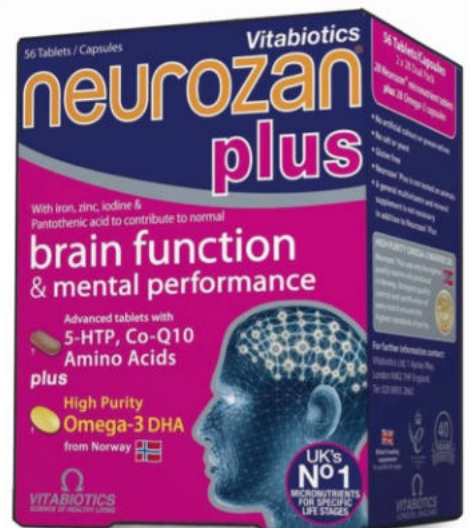
Neurozan® Original contains a specially developed combination of nutrients and is certified by *Food For The Brain*.

Neurozan® Plus dual pack is for even greater nutritional support with high purity Omega-3 from Norway. 

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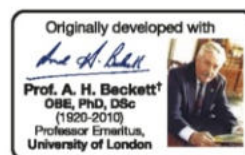
ORIGINAL



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Neurozan® is certified by pioneering charity **FOOD FOR THE BRAIN**. www.foodforthebrain.org

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People who eat nutritionally inadequate meals may especially benefit from vitamin and mineral supplementation. [‡] Iron, Zinc, Iodine.
[†] Professor Beckett is not cited in the capacity of a health professional, but as a product inventor and former Chairman of Vitabiotics.


VITABIOTICS
SCIENCE OF HEALTHY LIVING

TO DO LIST

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE



PICK OF THE MONTH



➔ HOW WOULD YOU change the future for the better? Children with a 'mute' button? Invisibility cloaks for idiots? Faster than a cheetah on rollerblades, science and technology are speeding ahead to solve the problems of tomorrow's world today, and as well as ridding the world of minor annoyances, there's the potential to yield profound and widespread change. So how should our future be shaped? Which innovations should take priority?

FutureFest, a festival of ideas and innovations in the heart of east London, aims to spark debate about questions like these. It's a two-day smorgasbord of creative thinking and intellectualism, curated by author, activist and Hue and Cry vocalist Pat Kane. From the bright and uplifting to the dark and dystopian, FutureFest will present a packed weekend of compelling talks, technology demos and crowd-sourced experiments, as you're invited to come and meet "some of the most disruptive minds on the planet".

The weekend is split into four quarters, which are loosely themed around extending life, emerging technologies, our impact on the Earth, and the

political economy of the future. Saturday's highlights include the herald of the sharing economy Rachel Botsman, techno-cellist Peter Gregson and bionic man Bertolt Meyer, who sports a cutting-edge but Smurf-esque blue prosthetic arm. As well as all that there'll be secret agents, the weather forecast for 2100 and a crowd-sourced experiment in futurology.

Sunday sees philosopher Roberto Unger analysing the future of religion and model Lily Cole promoting impossible.com, her new social network which promotes altruism, loveliness to all and a benevolent gift economy. Food futurologist Morgaine Gaye will prepare lunch in the Gastrodome while Iceland's Pirate Party founder Smári McCarthy will explore life in a digitised world.

The festival is organised by Nesta, an independent charity with a mission to help people bring great ideas to life. Its goal here is to create an immersive experience of what the world might feel like over the next few decades. Do try and make it along if you can, but if you can't then you can always wait 20 or 30 years and find out for yourself.

HELEN PILCHER

DON'T MISS!



British Science Festival

See Dr Michael Mosley (pictured), Lord Martin Rees and other big names from the world of science. **p96**



Grand Theft Auto V

The long-awaited latest instalment in Rockstar's genre-defining franchise is finally here. **p101**



Drunk Tank Pink

A new book examines the surprising factors that can influence our thoughts and actions. **p102**



VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

28 AUGUST

Lates: Photography

Science Museum, London, 6.45-10pm, free,
www.sciencemuseum.org.uk



DISCOVER MORE ABOUT the science of photography at this adults-only evening event. It's part of the popular Lates series, dubbed 'drinking and thinking' by visitors. Alongside talks are a pub quiz, comedy show, speed dating and a silent disco under a canopy of rockets in the Exploring Space gallery. It could be the perfect way to meet a fellow *Focus* reader.

30 AUGUST

Crime Scene Live

Natural History Museum, London, 7-10pm, £40 (members £30),
www.nhm.ac.uk/lates



THE NATURAL HISTORY Museum has a killer on its hands. Step into the shoes of a crime scene investigator and, with the help of real forensic scientists and detectives from Scotland Yard, gather evidence from a grisly murder. Beware not to bungle any leads though – the case will go to trial where barristers will call your evidence into question.

5-11 SEPTEMBER

Orkney International Science Festival

Various venues, Orkney, £4/£2, www.oisf.org



WE TOLD YOU how to actually make a zombie a few issues back (May, 254), so it might be prudent to attend a living-dead survival guide from theoretical zombiologist Ian Alexander. This is just one of an eclectic mix of talks at the festival, which features everything from the science of black holes to the secret maths of knots and dancing.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)



EDITOR'S CHOICE

Discover the medical sciences with Dr Michael Mosley at the British Science Festival

7-12 SEPTEMBER

British Science Festival

Newcastle, some free events, www.britishsociety.org/british-science-festival



WITH ONLY TWO years of school under his belt, Thomas Henry Huxley rose from humble beginnings to become one of the intellectual giants of the 19th Century. Despite all his achievements, he's probably best remembered for his spirited defence of Darwin's theory of evolution by natural selection – in particular, the heated debate between himself and Samuel Wilberforce, the Bishop of Oxford, in 1860 at the British Festival of Science.

Just as Huxley and Wilberforce came to blows, the big debate at this year's festival

will get temperatures rising over the subject of epigenetics – how the environment affects genes. Also at the festival are eminent scientists, such as Lord Robert Winston and Lord Martin Rees, as well as stars of the small screen, including BBC *Horizon* presenter Dr Michael Mosley and geologist Prof Iain Stewart, revealing the story of the continents.

But it's not all serious stuff. 'What's the point?' is a light-hearted look at why we bother doing science at all, while the comedy show 'Festival of the Spoken Nerd' brims with unashamed science geekery.

13 SEPTEMBER - 2 OCTOBER

TechFest

Aberdeen, prices vary, www.techfestsetpoint.org.uk



ABERDEEN, THE GREY city will get the grey cells working with the line-up of speakers at this year's TechFest, celebrating the 20th anniversary of the event. Have fun with daredevil science presenter Greg Foot and comedian Helen Keen from Radio 4's *It Is Rocket Science*, before taking in some forensic anthropology with Prof Sue Black.

16 SEPTEMBER

Winning And Losing - the fight against infectious diseases

Royal Society, London, 6.30-7.30pm, free, <http://royalsociety.org/events>



DESPITE BILLIONS BEING spent to combat them, infectious diseases like AIDS and malaria aren't going away. At this talk, Christopher Dye (pictured), Director of Health Information at the World Health Organisation, reveals which infections have been and can be controlled, and which ones will continue to plague us in the future.

19 SEPTEMBER

Astronomy Photographer Of The Year

Royal Observatory Greenwich, London, free, www.rmg.co.uk



WHILE MOST OF our efforts to capture images of space would be so embarrassing we'd wish a black hole would swallow us, we can still enjoy the work of dedicated stargazers at the Royal Observatory. Marvel at images of distant galaxies, the Milky Way and the planets. But there's hope for us novices - there's also a prize for Best Newcomer.

27 SEPTEMBER

Science Uncovered

Natural History Museum, London, 4-11pm, free, www.nhm.ac.uk



FOR ONE EVENING, the Natural History Museum is opening its doors and drawers. Discover collections not normally on display, and meet world-class scientists face-to-face at science stations, debates and the science bar. What's more, a DJ will keep you up till midnight. No he's not called DJ Dippy...

SPEAKER OF THE MONTH

23 SEPTEMBER

Max Barclay

Royal Albert Hall, £25/£15, London, <http://tedxalbertopolis.com>



Who is he?

Bug man Max is the Collections Manager at the Natural History Museum in London. He looks after one of the largest and oldest beetle collections in the world, with 22,000 drawers of specimens dating back to Captain Cook's voyages.

Where has his research taken him?

Max has been on field trips to the most remote rainforests and mountain ranges in the world, and discovered numerous new species. In fact, 50 species have been named in his honour, the most recent being *Ischalia barclayi* - a metallic blue cardinal beetle.

What's he talking about?

With one in five species on Earth being beetles, we're sure he'll have a bug or two up his sleeve to discuss at this TEDx event.

UNTIL 15 SEPTEMBER

Fracking Futures

FACT Liverpool, 13 June - 15 September, www.fact.co.uk



Art holds a mirror up to fracking, a controversial new energy source



WITH A FACEBOOK group called 'Frack off', and pressure groups hounding the government, fracking has become the new political hot potato. Some say that fracturing shale rocks with high pressure fluid to release natural gas (see p71) can contaminate the water table and cause earthquakes. But as fuel costs rise, fracking could be a realistic alternative energy source in these power-hungry times. This provocative artwork shows 'hydraulic fracturing' on a micro-scale to highlight the issues surrounding the divisive new technology.



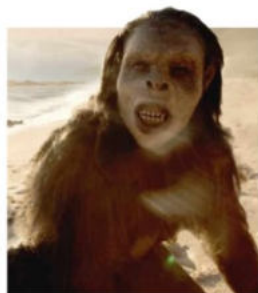
WATCH

TV, DVD, BLU-RAY & ONLINE
WITH TIMANDRA HARKNESS

FROM 26 AUGUST

Monster Week

Animal Planet, starts 26 August



THE US GOVERNMENT had to declare officially that mermaids do not exist after the first screening of *Mermaids: The Body Found*. Now *Mermaids: The New Evidence* forms part of a week devoted to the mythical and the unexplained. Also appearing are *Man-Eating Super Snake* and *Man-Eating Super Squid*. Probably not one for small children.

26 AUGUST

Mummy King Mystery

Discover History, 26 August, 8pm

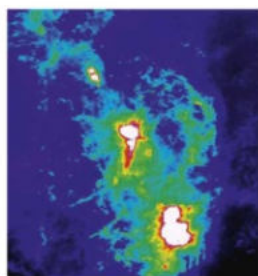


EMPIRE-BUILDER RAMESSES II was the greatest of Egypt's pharaohs – by his own account. Married to the legendary Nefertiti, he also had a 200-strong harem who bore him over 150 children. Prof Kent Weeks applies modern forensic science to the myths, drawing together clues from Egypt's largest tomb, an ancient skull (pictured) and the Old Testament.

2 SEPTEMBER

Invisible Universe

Eden, 2 September, 8pm



THEY USED TO show us things that were too far away, but today telescopes can use wavelengths the human eye can't even see. IRAS, the InfraRed Astronomical Satellite, creates never-before-seen images of the cosmos. In this documentary, find out how astronomers are using it to study colliding galaxies, the birth of stars and elusive comets.

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Worldwide's YouTube channel Head Squeeze

EDITOR'S CHOICE



Customers felt they had got their money's worth from the Ray Mears survival guide weekend

2 SEPTEMBER

Decoding Neanderthals

Eden, 2 September, 9pm

WHEN OUR ANCESTORS first arrived in Europe 60,000 years ago, they found Neanderthals already there. Archaeologists have been piecing together the story of how the Neanderthals lost the battle to survive in the Ice Age environment. But in 2010, genetics put a twist in the tale.

Neanderthals have been portrayed as our inferior relatives, distant cousins whose clumsiness and stupidity made it inevitable that they would die out. But when geneticist Svante Pääbo and his team reconstructed the

Neanderthal genome, they made a discovery that rewrote the story of who we are. Before they disappeared, our stocky cousins left a bit of their DNA behind – a genetic legacy that is found in every human being whose ancestors left Africa before the modern era. Chances are, there's a bit of Neanderthal in you.

What happened, back in the Ice Age, when the two human races encountered one another? And which parts of ourselves do we owe to our Neanderthal cousins?

16 SEPTEMBER

Resurrection Science

Eden, 16 September, 8pm



JURASSIC PARK WAS pure fantasy – or was it? As this film reveals, three researchers have made it their mission to use biotechnology and genetics to raise the dead. From Kyoto in Japan to MIT in the USA, the race is on to make science fiction a reality. Neanderthal, mammoth, dinosaur – are there any limits to how far science can turn back time?

17 SEPTEMBER

Next Megaquake

National Geographic, 17 September, 9pm



THE JAPANESE EARTHQUAKE in March 2011 was the largest in the country's history. More than 18,000 people died, in a country with the densest network of seismographs in the world. But the megaquake was the fifth worldwide in just eight years. Follow geologists racing to use what they learn from Japan to predict future quakes and save lives.

19 SEPTEMBER

Future Firepower

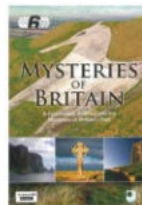
Discovery, 19 September, 10pm



Bob was baffled as to why he wasn't allowed to enter the remote control model aircraft competition

➔ TODAY IT'S DRONES versus suicide bombers, robots versus IEDs (Improvised Explosive Devices). But what is the future of military technology? This series attempts the near-impossible task of looking like a serious investigation of future peacekeeping, rather than a computer game-style dramatisation of war games. Remotely controlled weapons, high-tech aircraft and deadly ordnance are all on a menu that will either satisfy your inner war hero, or put you off the idea of armed force for ever.

DVD & BLU-RAY



Mysteries Of Britain

Demand DVD, released 23 September

YOU DON'T NEED to go to Egypt or South America to find unsolved mysteries. This BBC series looks into riddles of ancient British history – who, for example, were the Tower People of Shetland?



In Space

Demand DVD, released 23 September

TWO SERIES OF *In Space* examined what we know about the cosmos and what the future holds. This four-disc set takes you from the Big Bang to the commercial exploitation of the Moon.



The Magic Of The Big Blue

Go Entertain, released 16 September

THIS ANIMAL PLANET series was shot by underwater photographer Darek Sepiolo in HD, revealing the beauty of the undersea world from Indonesian coral reefs to the Galapagos Islands.

FROM 18 SEPTEMBER

Ultimate Airport Dubai

National Geographic, starts 18 September



WITH OVER A million passengers a week, 60,000 staff and 55 miles of luggage-moving equipment, Dubai International Airport is one of the biggest airports in the world. This series goes behind the scenes as a new concourse is prepared, new cabin crew are trained and routine repairs made to aircraft without losing time and money.

FROM 23 SEPTEMBER

Alien Encounter

Discovery Science, starts 23 September, 10pm



LOTS OF THOUGHT has been given to whether intelligent life exists beyond Earth, but surprisingly little to what we should do if we find it. In this series, astrobiologists, astrophysicists and science fiction writers are asked: when an alien ship signals to say ET and chums are on their way, should we lay the table or polish the guns?



LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

24 AUGUST

The Next Healthcare Revolution?

BBC World Service, 24 August, times TBC

SEQUENCING THE HUMAN genome was supposed to herald breakthroughs in fighting and even preventing disease. Bridget Kendall presents this edition of *The Forum*, inviting Thomas Frieden, Director of the Centers for Disease Control, to join Onyx Pharmaceuticals CEO Anthony Coles and FDA Commissioner Margaret Hamburg in discussing how genomics can help shape the next generation of medicine and public health.



When will efforts to sequence the human genome turn into medical breakthroughs?

21 SEPTEMBER

Arizona's Killing Fields

BBC World Service, 21 September, various times

IN THE ARIZONA desert, Mexican immigrants lie dead. Who are they, and how did they die? Research suggests would-be migrants are nearly 10 times more likely to die in the attempt as they were a decade ago. Forensic anthropologists try to discover the victims' identities and piece together the story of their last hours, days and weeks. Can this grim work help prevent more deaths occurring in the years to come?

28 SEPTEMBER

Isolation

BBC World Service, 28 September, various times

SOME SEEK ISOLATION, and some have it forced upon them. Either way, being entirely on our own for long stretches of time isn't something that comes naturally to most of us. Anahi Aradas meets various people who are forced to deal with isolation: a small group in Antarctica, a former Apollo astronaut and prisoners in Sweden. The prisoners are encouraged to practise yoga, but can that really compensate for being deprived of regular human contact?

WEEKLY

Shared Planet

BBC Radio 4, Tuesdays, 11am

THE SERIES THAT casts humans as the overpopulous neighbours coming into conflict with wildlife continues. Issues addressed during September include the pressures of growing enough food and the problems we've caused by introducing species such as rats to island habitats. In a programme on elephants, Saba Douglas-Hamilton reports from a conservation project in Kenya, while Monty Don explores the illegal ivory trade.



TV presenter Monty Don reports on the fight against the illegal trade in ivory



TOUCH

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WITH CHRISTOPHER PHIN

The Incomplete Map Of The Cosmic Genome

iPad
Trunkman Productions, £5.99

THIS APP BILLS itself as an interactive magazine/documentary. You subscribe – up to £9.99 for a year, though you get three months bundled for the £5.99 price – and new videos pop



in every month, with scientists, writers and comedians explaining why they love science and discussing the ideas they're excited about. It's chaotic but hugely engaging – and with Robin Ince as the host, you know it'll be good.

SLOOH

iPad
SLOOH, free (with in-app purchases)

THE SLOOH ROBOTIC telescope service, hooked into a global network of observatories, lets you watch live events in the night sky and rent an instrument to look at something in particular. And



now you can do it all from your iPad. There are no images of celestial objects included; instead you buy scheduled slots to have the cameras take your photos. That's all very exciting, but with prices from 69p to £2.49 and up, it could get a bit pricey.

UFO Files UK

iPhone, iPod touch, iPad
mixr.co, 69p



ON ONE HAND, you can't fault this app. It presents nearly 5,000 reports of UFO sightings that have been documented by the MoD's UFO Desk. The app now includes the last batch of sightings to be declassified, covering the final two years of the UFO Desk up to 2009, and for many of them the original scanned documents are also attached. Great! On the other hand, we are talking about little green men in flying saucers...

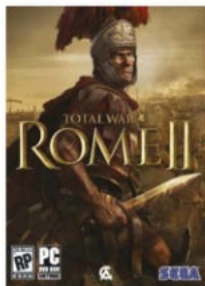
CHRISTOPHER PHIN is the editor of *MacFormat* magazine



PLAY

CONSOLE & COMPUTER GAMES

WITH NEON KELLY



Total War: Rome II

PC, Creative Assembly, £29.99

DEVELOPER CREATIVE ASSEMBLY returns to the setting of its most lauded game: classical antiquity-era Rome, where pristine togas and stabbed backs are the order of the day. As before, the action unfolds in two distinct arenas. On the field of battle you'll command up to 40 units at once in epic, tactical conflicts, then on the campaign map you'll manipulate political factions, convert rivals to your cause, and assassinate your enemies. *Dulce bellum inexpertis*, as the old saying goes – but don't let that put you off.



Puppeteer

PS3, Sony Japan, £29.99

HAVE YOU HEARD about the Moon Bear King? Neither had we, but apparently he likes to rob children of their souls to provide his castle with a constant reserve of ghostly servants. In this snazzy platformer from Sony Japan, the lunar-based ursine monarch rips the head off a small boy, Kutaro, who then attempts to regain his cranium with the help of a magic pair of scissors. It's a bewildering plot, but marionette-like characters grant *Puppeteer* an instantly memorable look.



New Super Luigi U

Wii U, Nintendo, £29.99

TAKE PITY ON Luigi: despite being significantly taller than Mario, he'll always be trapped in his brother's shadow. This is a disc release of what was originally a downloadable add-on for *New Super Mario Bros U*, featuring stages that are much shorter than those in the original game, but also a darn sight tougher too. Luigi himself is fiddly to control, with a freakishly high jump that takes time to master. Poor guy – even in his own game, he plays as a bit of a weirdo.



GTA's Michael was starting to feel the psychological strain of going on his seventeenth murderous crime spree in as many days

Grand Theft Auto V

PS3, Xbox 360, Rockstar, £39.99



You can scuba dive. You can leap out of a plane. You can steal a policeman's car, drive it the wrong way down the motorway, and crash it into the sea – indeed, this is still bound to be what most of us do the first time we play. Just because you can.

There are new ideas, too. Where previous GTAs offered one muddled antihero, here there's a trio of them: retired mobster Michael, adrenaline junkie Franklin, and a psychotic ex-army pilot named Trevor. You can switch between these miscreants at will, even in the heat of a mission, offering three perspectives on whatever carnage happens to be at hand. Customisable heists are a major focus of the action, so expect to spend a lot of time planning robberies and assembling a bespoke crew of professional undesirables.

And if all that wasn't enough, there's also an extensive multiplayer mode, with your tailored avatar essentially standing as the game's fourth character. Rockstar wants *GTA Online* to gain a serious online following; whether it succeeds or not, expect to be playing this for months.

➔ SO, HERE IT is. The arrival of a new *Grand Theft Auto* is always a notable event, but this one feels particularly significant. A five-year wait has fuelled expectation to dangerously insane levels; if Marty McFly had parked his DeLorean in front of the *GTA* hype train, it'd probably be in a dinosaur's colon by now.

Still, it's hard not to be excited by the raw facts. This is the biggest game that Rockstar has ever made, a project so huge that the Xbox 360 version has to come on two discs. Its virtual world is five times bigger than the Western wilderness of *Red Dead Redemption*, encompassing the city of Los Santos (Rockstar's satirical take on LA) and miles upon miles of surrounding countryside.



READ

THE LATEST SCIENCE BOOKS REVIEWED

H Hardback **P** Paperback

Drunk Tank Pink

The Subconscious Forces That Shape How We Think, Feel, And Behave

Adam Alter

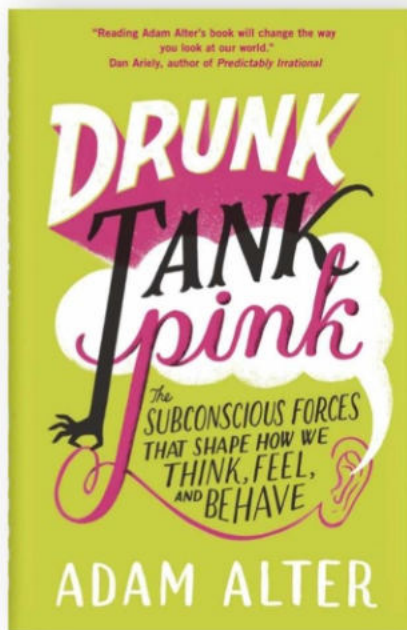
OneWorld **P** £11.99

EDITOR'S
CHOICE

THE PINK OF this book's title is a particular shade which, based on a 1979 medical report, was believed to have extraordinary powers. Just a few moments staring at a piece of cardboard painted this shade of bright pink had – it was claimed – extraordinary tranquilising powers. Men lost their strength, and their rage, under the effect of this 'non-drug anaesthetic' and soon everyone from sports coaches to prison wardens hoped they could take advantage of this psychological discovery.

Alter's book is a romp through hundreds of similarly surprising findings from studies into how we think, feel, and behave. From children being crammed into small rooms to investigate overcrowding, to making people watch car accidents to examine how situations can be sensationalised, the research is succinctly and honestly reported. It's also full references provided for the curious, and each chapter is peppered with anecdotes and real-world examples that help make the implications of the science clear.

"A fantastic introduction to the wealth of weird and wonderful psychology research out there"



The only problem is that there is such a large variety of phenomena described that you may well be left with no coherent impression, save that people's thinking is subject to an extraordinary range of forces. Our thoughts are subtly shifted by everything from the temperature to the half-noticed actions of people nearby. This clashes with a comfortable notion that our thoughts are ours and ours alone.

It is unfortunate that Alter titles his book after a piece of research that is so obviously exaggerated in power. If *Drunk Tank Pink* actually had an irresistible tranquilising effect we might be repainting the jail cells, or using it on rioters, but in fact the effect is not as strong, and the mechanism not as simple, as people wanted to believe. You will get the same impression with lots of the other phenomena reported in this book.

However, *Drunk Tank Pink* is a fantastic introduction to the wealth of weird and wonderful psychology research that is out there. Enjoy the often bizarre methods used to probe behaviour, but remember that for every one part of knowledge that Alter reports, there are nine parts uncertainty that don't make for such a good story.



TOM STAFFORD is a psychologist and the co-author of *Mind Hacks*

MEET THE AUTHOR



**Adam
Alter**

Apart from the 'drunk tank pink' of the book's title, are there any other colours that influence us?

All colours have a subconscious effect on us. A lot of research has been done on the colour red. We know, for example, that if you're trying to appeal to potential matches on a dating website, the best thing you can do is wear a red shirt. The same is true for hitchhikers: when female hitchhikers in a study changed their shirts every couple of hours, they were much more likely to be picked up by men when they were wearing red.

Why's that?

One reason might be that we associate red with the rush of blood to the face that comes with arousal or excitement. So the colour red might be a subtle signal that someone is romantically interested.

You say that our names can also influence us – how's that?

A lot of the research I've done is looking at a concept known as fluency. We've seen, for example, that lawyers tend to rise up the legal hierarchy quicker if they have easy to pronounce names. You could imagine two lawyers joining a firm, and on their first day some senior partner is choosing lawyers for a team. There's a slight preference in these semi-awkward situations for someone who has a simpler name just because there's less anxiety with pronouncing it. Over time, these small differences are magnified.

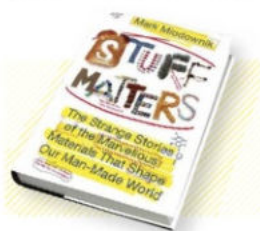
Should we learn to recognise these effects?

There are many small steps we can take to improve our outcomes at work, romantically, and on the sports field.



MORE ON THE PODCAST

Listen to the full interview with Adam Alter at sciencefocus.com/podcasts



Stuff Matters

The Strange Stories Of The Marvellous Materials That Shape Our Man-Made World

Mark Miodownik

Penguin **P** £18

I'M ON A plane finishing *Stuff Matters*. A quick scan of my surroundings reveals Mark Miodownik's thesis: aluminium, fabric, plastics, glass, paper, steel. In short, I'm sitting within an extraordinary collection of materials. The woman asleep next to me has a lump of carbon on her finger. I'm tempted to wake her with some fresh facts: how a De Beers advertising campaign (diamonds are forever) is likely the sole reason she's wearing one, or that her rock is about a million, billion, billion atoms in a perfect pyramidal state that's slowly losing its lustre and turning to graphite.

But *Stuff Matters* is more than just a 'believe-it-or-not' fact-fest. At its heart is the story of our complex relationship with the world we've created, seen very much through the author's eyes. The book is structured around Mark's personal history and fascination with a landscape that is in full view to us all and yet remains invisible. What's clear is that material science is redefining our world in ways that were unthinkable a generation ago. This book is a great place to begin to understand that story and revel in one man's passion.



DALLAS CAMPBELL is the presenter of *Supersized Earth* on BBC TV



Fooling Houdini

Adventures In The World Of Magic

Alex Stone

William Heinemann **P** £20

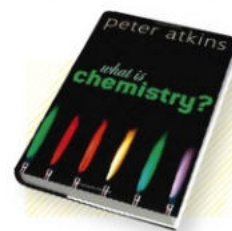
IN 2006, AMATEUR magician Alex Stone was virtually laughed off stage at an international magic competition. Determined to find redemption, he applied himself to magic with renewed determination. It is this quest Alex details in *Fooling Houdini*.

Alex writes openly about the subculture of magic and its methods. It's a colourful adventure full of improbable characters, from blind cardsharps to street hustlers. However, recently science has become spellbound by the work of the magician. Alex cites the research of psychologists and neuroscientists investigating the magician's use of misdirection. He performs a card trick explained by statisticians Persi Diaconis and David Bayer, and teams up with Professor Arien Mack at The New School, New York, to devise a watch-stealing experiment that measures tactile insensitivity.

Alex Stone might not be the world's best magician, but he's written a very engaging book that gives a good insight into the science behind the tricks. Alas, filled with 'secrets', it probably won't go down too well with his fellow magicians.



DAVID BRITLAND is a writer specialising in magic and psychology



What Is Chemistry?

The Infrastructure Of The World

Peter Atkins

Oxford University Press **P** £8.99

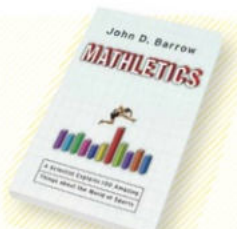
ANSWERING A QUESTION like 'what is chemistry?' in 111 pages and one table (the periodic one) is a tough job. And Peter Atkins is just the person to do it, having authored some 70 other books.

Atkins tackles the central tenets of chemistry that many may have struggled with in the past. From his explanations of the esoteric table that hangs at the front of chemistry labs to the fundamentals of thermodynamics, Atkins lifts the veil by offering clear, precise explanations, with minimum jargon (and this is always well defined). The book then wraps up with a demonstration of the pivotal role, for both good and ill, that chemistry plays in our modern lives and culture.

Overall Atkins's no-nonsense, didactic approach should allow any interested reader to quickly grasp the nuts and bolts – or more appropriately the atoms and molecules – of chemistry even if their school science lessons were just an excuse for a nap. There are other popular science books out there that dress chemistry up in a plethora of fascinating tales and anecdotes, but if you want a crash course then you won't find better than *What is Chemistry?*



DR MARK LORCH lectures on biological chemistry at the University of Hull



Mathletics

A Scientist Explains 100 Amazing Things About Sport

John D Barrow

Vintage Books

P £8.99

ALTHOUGH MUCH OF my time at university was filled with maths and sport, I never managed to combine the two. But *Mathletics* aims to do just that, using mathematical reasoning to explore the quirks of the sporting world.

Over the course of 100 short chapters, the book tackles the sort of questions that would puzzle many an armchair pundit, such as why basketball players appear to hang in the air when they jump, or whether having a cox speeds up a rowing boat. The answers are illustrated with plenty of stories and trivia, from teams trying to score own goals to the origins of tennis scoring.

Not all chapters work well, however. Claims that Premier League football results are random are too vague, and the final chapter discusses a game show puzzle – odd for a book about sport. Equations are often delivered as statements of fact, rather than assembled in a logical way. As a result, some sections would be hard to follow without knowledge of calculus. While there are some interesting insights, unfortunately there are too many hurdles in between.



ADAM KUCHARSKI has a PhD in maths and is an award-winning science writer

OCTOBER ISSUE
ON SALE 19 SEPTEMBER

THE UNIVERSE: THE STORY SO FAR

FROM THE BIG BANG TO THE PRESENT DAY,
NEW DISCOVERIES ARE REVEALING THE
HISTORY OF THE COSMOS

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PHOTO: THINKSTOCK

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MINDGAMES PUZZLE
SOLUTION
No cheating! Don't look at
this until you've attempted
the puzzle on p111



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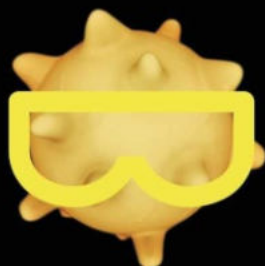
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BRITISH SCIENCE FESTIVAL: NEWCASTLE 7 – 12 SEPT 2013

britishsciencefestival.org



The British Science Festival was been established in 1831 and travels to a different UK city each year. This year the Festival will be held in Newcastle with hosts Newcastle University and associate partners Northumbria University and Newcastle City Council.

Launch

To launch the Fest, the British Science Festival will be working in partnership with EAT! Festival to provide a feast of tasty treats for all to enjoy. The excitement continues throughout the weekend with some family fun activities, science shows and hands-on fun. From science buskers to sleeping with dinosaurs, the Festival will have something for all ages and interests in the family.



Huxley debate

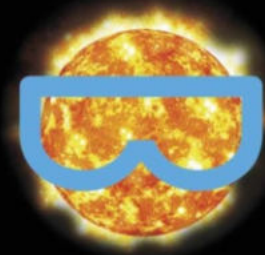
For the first time in over 150 years, the Festival will be emulating one of science's most famous debates. Thomas Huxley made the case for evolution via natural selection against the Lord Bishop of Oxford, Samuel Wilberforce. The showdown helped change how the world engaged with scientific issues of the time and inspired arguments and debates for years afterwards. Join the Festival 153 years later as they reignite that spirit and excitement with the first of a series of annual Huxley debates. Two experts will argue it out in a serious but energising debate.

You heard it here first

For the first time ever, the Festival will be hosting the event 'You heard it here first'. This will be your chance to future-gaze with some of the brightest new researchers. Hear from scientists in the early stages of their career talking about their groundbreaking research. Hear what the next big thing in science and technology will be and go up against a team of journalists to vote for your favourite researcher and new science topic.

Bookings for the British Science Festival are now open: **08456 807 207**

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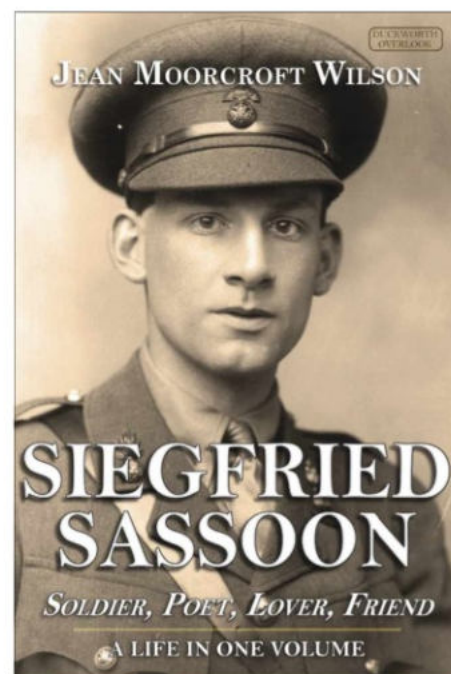
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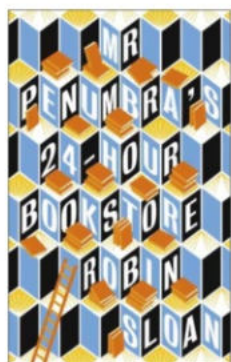
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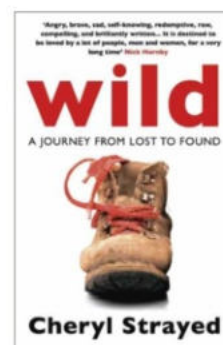
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MINDGAMES



Pit your wits against these brainteasers by David J Bodycombe, question-setter for BBC Four's *Only Connect*

PRIZE PUZZLE

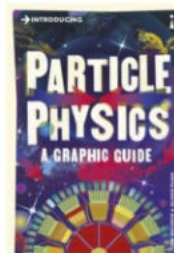
These are the 1st, 4th, 6th and 8th diagrams from a logical sequence. What should the 14th in the series look like?



WIN! PARTICLE PHYSICS: A GRAPHIC GUIDE

The first five correct entries win a copy of *Particle Physics: A Graphic Guide* by Tom Whyntie (Icon Books, £6.99).

Post your entry, marked 'Prize Puzzle 259', to: *Focus* magazine, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 19 September 2013. We regret that we cannot accept email entries for this competition. See sciencefocus.com/winners for a list of previous winners and solutions.



See bottom of p104 for terms and conditions. Congratulations to Mike Harman (Swindon) and Blaine Malone (County Down) who answered July's Prize Puzzle correctly to each win a copy of *Test Your Brain* on DVD.

Q1

While sitting in a barber's chair, I noticed in the mirror that the word BARBERS was painted on the shop window directly behind me. How did it appear to people outside the shop?

Q2

Six letters have been delivered to the wrong household. What is the maximum number of one-for-one swaps required to right the situation?

Q3

Starting with 'Grand Opera, Opera House...' what is the last word used in the complete sequence?

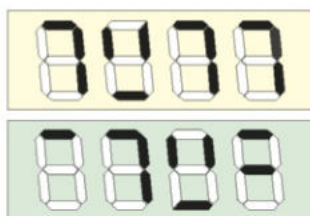


Q4

If someone was quoted as saying 'I was n years old in the year n^2 back in 1971, when were they born?

Q5

What word can be made from these two punched cards?



Q6

Pair up these small words – logically, which one is left out? MY, KNEW, PIT, NO, EAT, TIE, NEWT

Q7

Add the same number or mathematical symbol three times to make this correct. Now find another solution: $35 = 6$

Q8

Complete the grid so that each row, column and long diagonal contains the letters in the word SQUARE. One letter per space.

		S	A		
				S	
		U			
Q			R		
		E			

SOLUTIONS

Q1) The right way around also.
Q2) Five – for instance, if the letter for number 1, 2, 3, 4, 5, 6 is delivered to 2, 3, 4, 5, 6, 1.
Q3) The sequence goes Grand opera, Opera house, House party, Party, guest, Guest star, Star chamber, Chamber music, Music box, Box office, Office block, Block head, Head dress, Dress code, Code name.
Q4) Born in 1892. They were 44 years old in 1936 (44 squared).
Q5) Flip the upper card left-right and

Q6) The Kneep (tiny), 'Pit Ear (petite) and 'My Newt' (minute) all sound small. 'No' is left over.
Q7) (a) 3151 = 61; (b) 3050 = 60. (Q8) See illustration on p104.

turn the other card upside-down then overlap to form the word CODE.
Q9) 'The Kneep (tiny), 'Pit Ear (petite) and 'My Newt' (minute) all sound small. 'No' is left over.
Q10) (a) 3151 = 61; (b) 3050 = 60. (Q8) See illustration on p104.

QUICK QUIZ

Test your knowledge of the oceans

Q1

The Gulf Stream is in the...

- a) Atlantic Ocean
- b) Pacific Ocean
- c) Indian Ocean

Q2

Which strait connects the Arctic and Pacific Oceans?

- a) Menai Strait
- b) Strait of Gibraltar
- c) Bering Strait

Q3

What's the maximum-known depth of the Mariana Trench?

- a) 5.9km
- b) 10.9km
- c) 15.9km

Q4

What term is given to the ocean layer closest to the surface?

- a) Bathypelagic zone
- b) Mesopelagic zone
- c) Photic zone

Q5

What Pacific current flows northeastward past Japan?

- a) Kuroko Current
- b) Kuroshio Current
- c) Kurosawa Current

Q6

The Hawaiian Islands are located in which ocean?

- a) Indian Ocean
- b) Pacific Ocean
- c) Southern Ocean

Q7

"Seawater is around ___ salt, by weight."

- a) 3.5%
- b) 33.5%
- c) 63.5%

ANSWERS:

1a, 2c, 3b, 4c, 5b, 6b, 7a

YOU ARE:

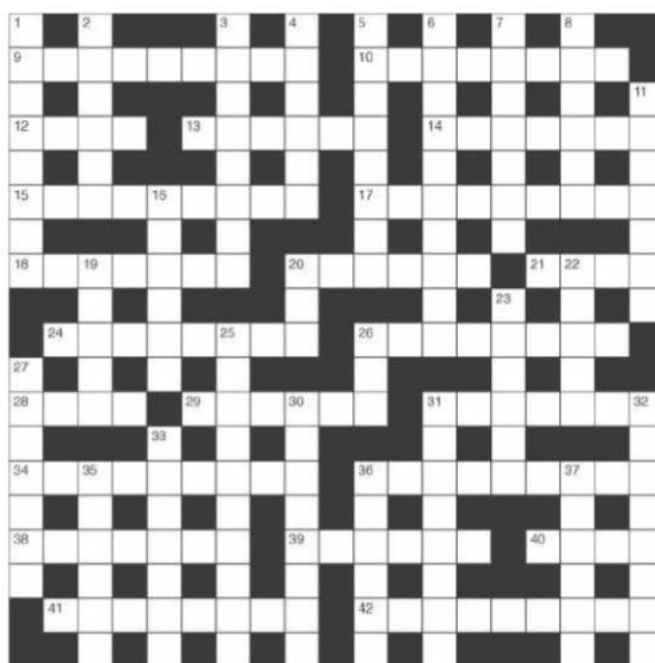
0-3 All at sea

4-5 Making waves

6-7 An ocean of wisdom

FOCUS CROSSWORD No 155

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ACROSS

- 9 Woman altered mine with uranium or another element (9)
- 10 Bustle around by railway, having a lot of wind (8)
- 12 Pressure that may be latent (4)
- 13 The problem you're looking at (6)
- 14 Rowers get victory - only on paper (7)
- 15 Fastening makes cretin opt the wrong way (6,3)
- 17 Insect used by the RAF in WW2 (5,4)
- 18 Jotter gets message home (7)
- 20 A student is after fish bone (8)
- 21 Creepy-sounding lake (4)
- 24 A fraction may be lacking propriety (8)
- 26 Like a bloody major route (8)
- 28 In favour of a South Pacific craft (4)
- 29 Part of the mouth provides taste (6)
- 31 Part with union chaps seen on the road (7)
- 34 Force charm into part of the nucleus (9)
- 36 Computer diagram shows wolf somehow caught deer (9)
- 38 Consider what a mirror does (7)
- 39 School rendered inane colour (8)
- 40 Harold only saw the light (4)
- 41 Visual problem forced gal to turn to deep sleep (8)
- 42 Source of iron obtained by ethical procedure (9)

DOWN

- 1 Thor managed to get image on camera tube (8)
- 2 Reported direct watery connection (6)
- 3 Offer to have cups embellished with one tooth (8)
- 4 Aggressive woman gets the largest flower (6)
- 5 He may be conscientious, putting gold thing first (8)
- 6 Pirate's gun affects big star (10)
- 7 Stair constructed with silver from Aristotle's birthplace (7)
- 8 Cave has sadly got decay inside (6)
- 11 Company finds each problem gets left within hearing (7)
- 16 Deal internationally in old wine (6)
- 19 Time for some music (5)
- 20 Copper right to get a dog (3)
- 22 Earl managed to get married in a field (5)
- 23 Very cold in the sea (6)
- 25 Factory put into a new farming estate (10)
- 26 Time of pageantry (3)
- 27 Wild caper involving Greek character and peach skin (7)
- 30 He can't remember if CIA means trouble (8)
- 31 Random movement from ex-PM, a Scot (8)
- 32 Gas makes intern go crazy (8)
- 33 I must work with exercise as an incentive (7)
- 35 Air Force fellow joins the French lottery (6)
- 36 Swindle and hide (6)
- 37 A duty to get one a lack of co-ordination (6)

SOLUTION TO CROSSWORD No 152

Mike Timpson, Peter Haworth, Andy Champion, Julie James and SD McAllister solved issue 256's puzzle and each receive a copy of *30-Second Astronomy*.



WIN! MYTHBUSTERS SEASON 1 ON DVD

The first five correct solutions drawn will each win a copy of *MythBusters Season 1* on DVD (Discovery, £15.41). Entries must be received by 5pm on 19 September 2013. See below for more details.



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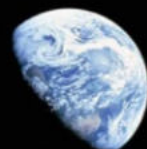
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Post entries to Focus, September 2013 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to september2013@focuscomps.co.uk by 5pm on 19 September 2013. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 104. Immediate Media, publisher of Focus, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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INTO THE FUTURE

STEPHEN BAXTER

Civilisation wouldn't survive the weapons of the future...

AUGUST 5TH 2013 saw the 50th anniversary of the signing of the Limited Test Ban Treaty, by the United Kingdom, the Soviet Union and the United States. Agreed at the height of the Cold War, this treaty prohibited test detonations of nuclear weapons except underground. The idea was to slow the arms race, and to stop the excessive release of nuclear fallout.

The Treaty was a triumph of diplomacy. There have been a few violations, when fallout escaped from underground tests in the USSR and US in 1965 and 1970 respectively, and nuclear powers yet to sign the treaty include China, France and North Korea. But fallout products in the air have dwindled; the amount of carbon-14 in the atmosphere – a key indicator of fallout – has been reduced from a peak of more than twice its background level in 1963 to only a little above the background today. And, of course, we have not yet succumbed to all-out nuclear war.

But what of the next 50 years? We are still mostly a planet-bound culture. If we move off the planet we will master energies on a much larger scale even than nuclear – energies that, if used in conflict, could have effects that would dwarf even a nuclear war. Published three years after the Test Ban Treaty, Robert Heinlein's novel *The Moon Is A Harsh Mistress* depicted a war between the Earth and Moon, in which lunar dwellers, without conventional weapons, simply fired lumps of moon rock into the Earth's gravity well. There was no need for explosives; the sheer kinetic energy – that is, the energy of movement – of a big rock falling from the Moon was enough to flatten a city block.

Heinlein's was an acute prediction. We don't need to consider the details of weapons systems; the sheer kinetic energy of space-borne objects is an indicator of an interplanetary culture's ability to do damage.

Britain is currently building two Queen Elizabeth class aircraft carriers, due to come into service in 2016. These 'supercarriers' will mass 65,000 metric tonnes each. If we were to build a space-going warship of such a size, simply to lift it into space – that is, to give it Earth's escape velocity of 11km/s – would require a kinetic energy equivalent to one megaton of TNT (MT) (one MT is about 4,000 terajoules). That's about 60 Hiroshima bombs. If such a craft collided with Earth, all that energy would be returned in a single devastating blast.

It gets worse. If the craft were capable of interplanetary flight at a respectable 100km/s – sufficient to reach Mars in a few weeks – a collision with Earth would deliver a punch of around 80MT, more



War of the worlds: a lunar colony could decimate Earth simply by firing rocks at it

“There was no need for explosives; the sheer kinetic energy of a big rock falling from the Moon was enough to flatten a city block”

than the yield of the largest nuclear weapon ever detonated, the 'Tsar Bomb' exploded by the USSR in October 1961 (57MT). Following an impact with Earth, a more advanced ship capable of one per cent of the speed of light – able to reach the outermost planet Neptune in 17 days – would deliver about as much energy as mankind produces in a year. This is about seven times as much energy as a modern-day all-out nuclear war. An interstellar craft like the Venture Star of the movie *Avatar*, which cruised at 70 per cent of the speed of light and could reach the nearest star in a few years, would deliver a punch as large as the impact of a 50km asteroid: this would be an extinction event.

Of course similar threats could be deployed against colonies on other worlds. For instance, a domed colony on Mars or the Moon could be very vulnerable to attack from above.

Hopefully by the time we are colonising the planets we will have put our propensity for conflict behind us, because we probably wouldn't survive an interplanetary war. ■

STEPHEN BAXTER is a science fiction writer whose books include *The Science Of Avatar* and the *Northland* series

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